UNIVERSITY OF ALBERTA

A TAXONOMIC STUDY OF THE POCKET GOPHERS OF ALBERTA

Mammalia: Geomyidae: *Thomomys talpoides* (Richardson)

by

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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "A Taxonomic Study of the Pocket Gophers of Alberta" submitted by Sandy James MacDonald in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

This study of geographical variation in Alberta populations of *Thomomys talpoides* Richardson is based on 422 adults from 11 areas. Variation among 44 characters was studied using an I.B.M. '360' computer to calculate the mean, standard deviation, standard error and other statistical parameters on each population.

Two subspecies are recognized: *Thomomys talpoides talpoides* (Richardson), the members of which range from the southern border of the province to the northern border of the Aspen-parkland, and *T. t. cognatus* Johnstone, from eastern British Columbia and the Crowsnest Pass region of western Alberta. The populations formerly referred to as *T. t. andersoni* Goldman are consubspecific with *T. t. talpoides*, and these names are therefore considered synonymous.

A discontinuity between the ranges of the subspecies suggests that each has entered the province independently from a different direction. A discontinuity within the range of *T. t. talpoides* is probably the result of extermination by man through current agricultural practices.

ACKNOWLEDGEMENTS

I wish to acknowledge my indebtedness to my committee members for their guidance throughout the duration of this study: to Dr. W.A. Fuller for his direction; to Dr. F.C. Zwickel for his advice in the preparation of the manuscript; to Dr. D.A. Boag for his advice and criticism of the thesis; to Dr. G.E. Ball for his advice on taxonomic procedures and his criticism of the thesis.

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INTRODUCTION

Three subspecies of the pocket gopher (*Thomomys talpoides* Richardson) are currently recognized in Alberta. This is the most recent of a series of classifications dating back to 1928 (see Appendix I for details). Earlier classifications were often based on limited material and relatively few physical characteristics (six to ten).

The purposes of this study were many. First, I wished to evaluate osteological and non-osteological characters to determine which were of the greater use in mammalian taxonomy. Second, I wished to make an analysis of the possible history and origin of Alberta pocket gophers and the effects of semi-isolation on adjacent populations of these animals. Third, I wished to examine the current recognized subspecies of *Thomomys talpoides* occurring in Alberta to determine if they were sufficiently distinct to warrant taxonomic recognition using accepted criteria defining the subspecies taxon. Fourth, I wished to determine the sample size needed for a taxonomic study of any other group of small mammals using my sample sizes as a guide. Fifth, I wished to evaluate the use of a computer in the handling of data gathered in taxonomic studies.

TAXONOMIC HISTORY

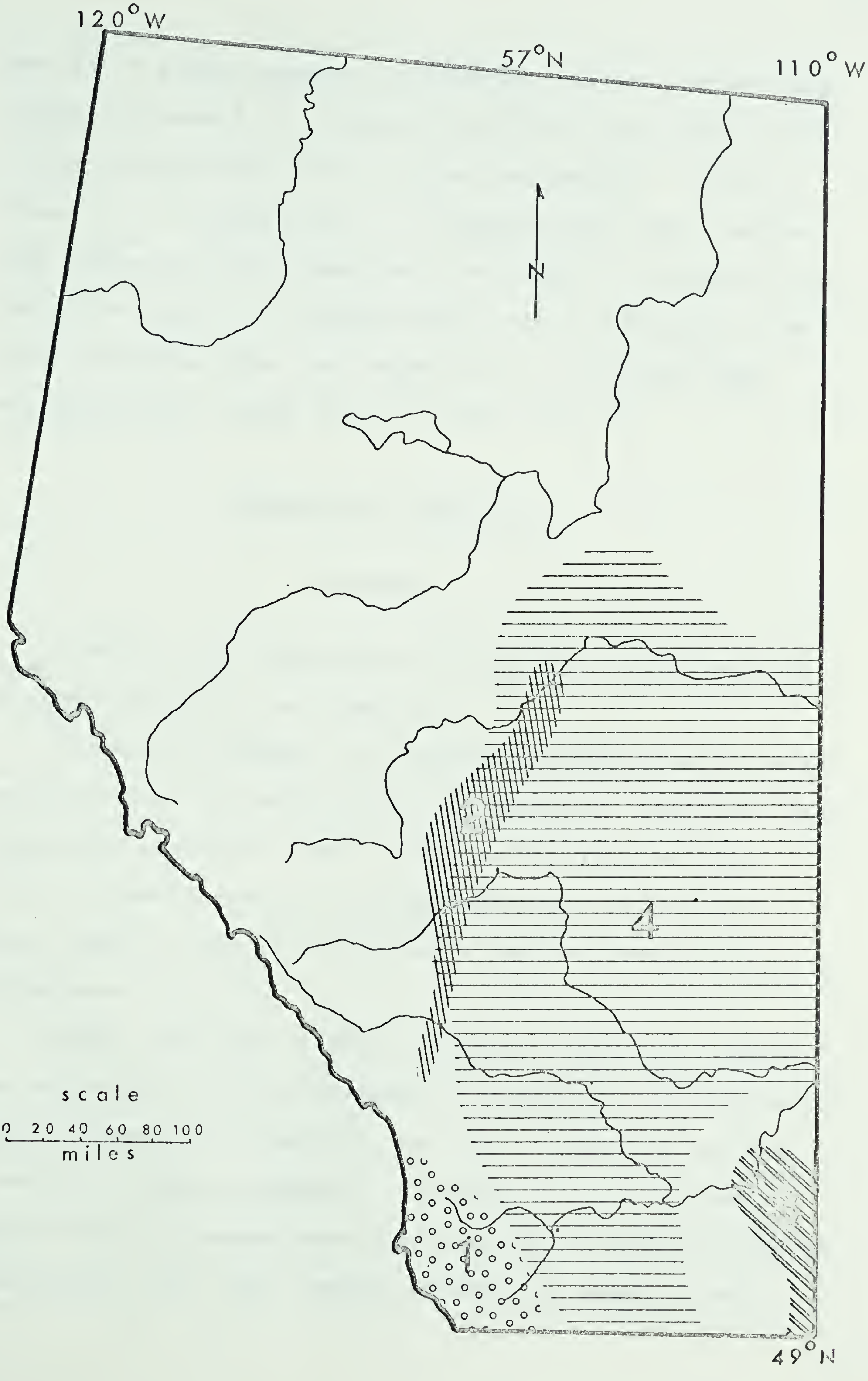
The number of subspecies of *Thomomys talpoides* recognized in Alberta has ranged from one (True, 1885) to (as many as) six (Bailey, 1915; Goldman, 1939; Johnstone, 1954; Miller and Kellogg, 1955).

Richardson (1828) named the pocket gophers of Alberta *Cricetus talpoides*, but did not describe subspecies. During the period from 1828 to 1858 the name changed 10 times (Appendix I). Baird (1858) erected the genus *Thomomys* to include the northern pocket gopher. No regional groups had been described up to that time. True (1885) gave the first subspecific designation (*Thomomys talpoides talpoides*) to Alberta pocket gophers. In 1915 Bailey retained this subspecies but added another species and three new subspecies: *Thomomys fuscus fuscus, T. f. loringi, T. t. talpoides, T. t. bullatus*. The geographical distribution of these taxa in Alberta is indicated in Figure 1.

Pocket gophers from the Medicine Hat region were named *T. t. andersoni* by Goldman (1939). He also combined, at the species level, *fuscus* and *talpoides* bringing all Alberta pocket gophers under the species name *talpoides*. Johnstone (1954) indicated that pocket gophers from the Crowsnest Pass area represented a new subspecies *T. t. cognatus*. Thus, in 1954, the literature listed six sub-

Figure 1. Geographical distribution of pocket gopher taxa in Alberta as plotted by Bailey (1915).

1. *Thomomys fuscus fuscus*
2. *T. f. loringi*
3. *T. talpoides bullatus*
4. *T. t. talpoides*


120°W
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species of pocket gophers in Alberta. Miller and Kellogg (1955) excluded *T. t. fuscus* from Alberta and Soper (1964) further reduced the list to three subspecies. He combined *T. t. loringi* and *T. t. talpoides* and thus implied that there were not enough data available to substantiate the claim that *T. t. loringi* was a valid subspecies. He also considered that the range of *T. t. bullatus* does not extend far enough north to enter Alberta.

TAXONOMY AND SUBSPECIES

Taxonomy

There are two approaches to taxonomy: the classical, as contrasted with the numerical.

Classical taxonomy is a method of classification which has prevailed for centuries and is based on relatively few characters chosen for their value to distinguish taxa. Thus, a classification is often determined using very small sample sizes (1 to 15) and a limited number of characters (3 to 10).

Sokal and Sneath (1963) discussed 'Numerical Taxonomy' and explained it as an approach to biological classification which attempts to eliminate, as much as possible, errors inherent in human judgement. Instead of quantitatively appraising the resemblances of organisms on certain favored characters, this 'new' method attempts to amass as many

distinguishing characters as possible, giving equal weight to each. A taxonomist using this approach evaluates the similarities mathematically and groups together those organisms with the most characters in common. The aim of the system, although not yet fully achieved, is to rid taxonomy of its subjective nature so that any two scientists, given the same set of characters but working independently, will arrive at the same estimates of the resemblance between two organisms.

Until the advent of the computer, limitations of human memory and computing ability seemed to set a limit to the number of characters and size of samples that could be used in taxonomy. Computers are able to store and work with the data from many more characters and much larger samples than humans and thus seem to be valuable taxonomic tools. Larger sample sizes and more characters reduce weight on any single character and may lead to a more precise classification.

Taxonomists generally accept the fact that it is desirable to use large numbers of characters in classifying organisms. However, most have used from three to ten characters (measurements and color) to place biological specimens in the correct specific and subspecific taxa. Sokal and Sneath (1963) contend that using so few characters, which are often highly variable, places too much weight on these characters for comparative purposes. They argue that many randomly chosen characters, each with the same value,

would facilitate the mathematical comparison of animals and thus decrease the possibility of personal biases. They argue that, in classical taxonomy, if a different set of characters were used, a different classification might result.

Following the arguments of Sokal and Sneath (1963), I attempted to classify Alberta pocket gophers using colour, number of mammae, number of vertebrae, and 44 measurements, of 422 adult animals. Some of the measurements were combined to form ratios. These data were then analyzed using the I.B.M. '360' computer.

Subspecies

Recently, the definition of the taxon 'subspecies' has been the subject of much discussion by many authors who have expounded two opposing points of view; (1) that the subspecies category is useful and should be retained, and (2) that the subspecies category is not useful and should be dropped.

Wilson and Brown (1953), and Burt (1954), indicate that there is widespread dissatisfaction with the subspecies concept and its application in zoology today.

Criticism by most taxonomists seems to be directed against one or both of the following assumptions: (1) that a subspecies is a definable biological unit; and (2) that the subspecies is a taxon like the species but on a lower level, and thus need not be as rigidly defined as the species taxo

Burt (1954) gives a short history of the origin of the

term 'subspecies'. He states that when species were represented by small samples from widely distinct areas, the samples were different enough to be regarded as distinct species. With the advent of better collections showing continuous geographic ranges of obviously the same species, geographic subspecies became essential. At this time there arose a school of taxonomists whose main consideration seemed to be the description of new subspecies. This school used small differences among population samples as a basis for recognizing subspecies.

Some taxonomists, for example Mayr, Linsley, and Usinger (1953), stated that most defined subspecies are part of a cline rather than a unit of a polytypic species.

Taxonomists who are dissatisfied with subspecies have proposed two alternatives. (1) To replace the trinomial with the concept of the 'cline'--this should work well where a conspecific group of populations has an extensive but continuous distribution. (2) To refer to a given population by its 'binomen' and its geographical location--this assumes that animals from different areas are equally different from all those from all other areas. This alternative would not show degrees of difference.

Mayr (1953) stated that the subspecies taxon is subjective and should be used sparingly as there is nothing to be gained by excessive splitting of continuous clines. Burt (1954) agreed with Mayr and wrote that study of a continental species with a more or less continuous

range would best be facilitated if subspecies were disregarded and work were concentrated on geographical variation. He also noted that geographically isolated populations result in many taxonomic problems. He states that in these instances individual judgement must be relied upon. If laboratory breeding experiments cannot be carried out then the decision should be based upon morphological differences from, or similarities to, the nearest large population. This decision should be either to treat the isolated population as a distinct species or as part of a more widespread species.

In general, taxonomists seem to agree on three points: that the arguments against subspecies can be used against any taxon which is composed of groups of subordinate taxa; that a subspecies is an arbitrary taxon, even in cases where there is no difficulty defining a given subspecies; and that the object of recognizing subspecies is to provide a utilitarian device for the classification of population samples.

I think the subspecies category is useful and will use it in this thesis as a means of reflecting an actual pattern of variation and as a means of referring to a certain group of animals (after Willis, 1967). However, I agree with Burt (1954) and his statement, that the indiscriminate naming of subspecies leads to confusion, and so I will endeavor to eliminate meaningless subspecific names now used to describe the pocket gophers of Alberta.

Subspecific Criteria

I have accepted the following criteria for recognition of subspecies:

(1) The population must presently be geographically isolated from other populations of the same species.

(2) The population must be significantly different in two or more morphological characters from other populations.

(3) The population must be genetically different from adjacent populations. This is difficult to test but implies that differences must be genotypic, not phenotypic.

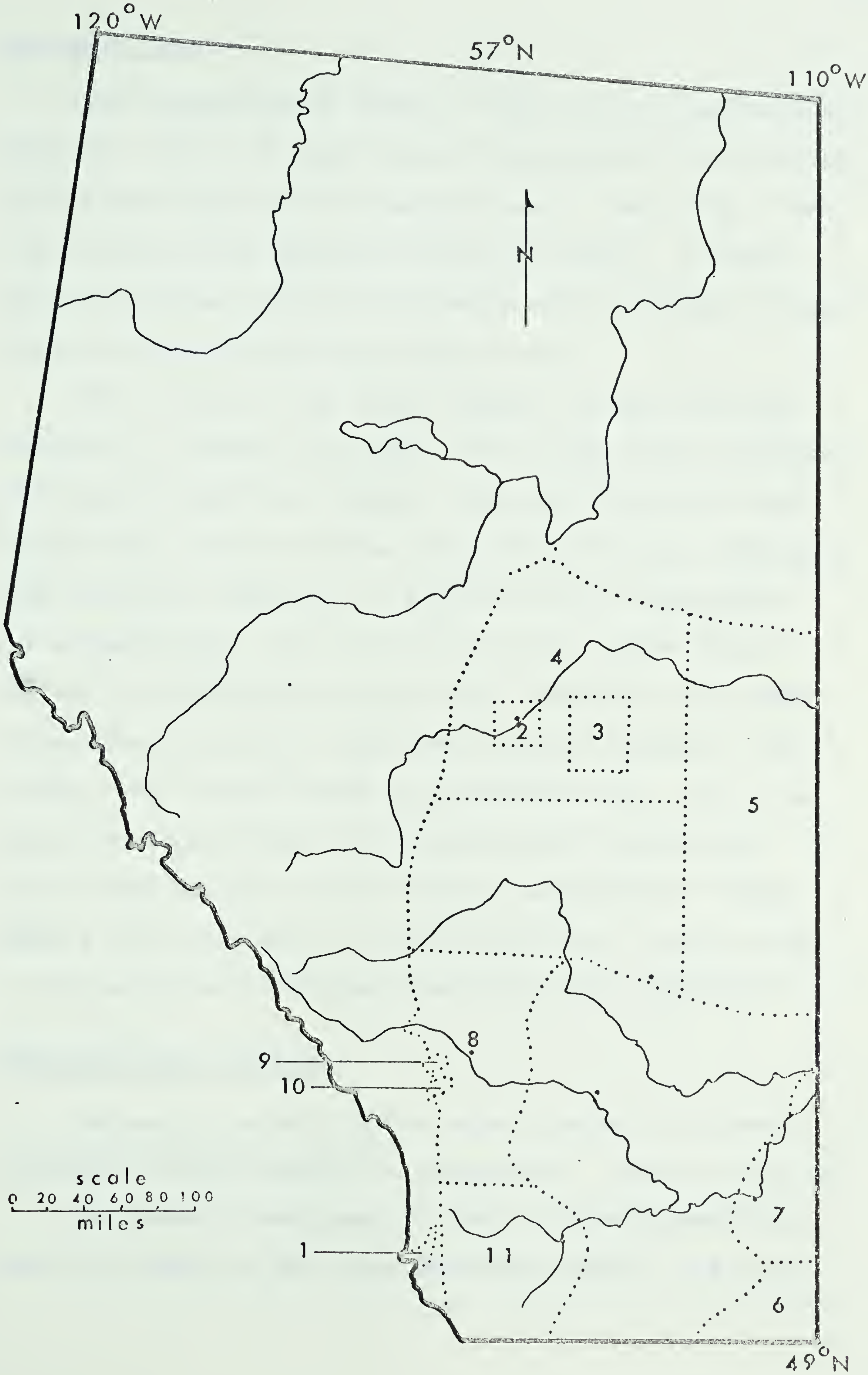
(4) Animals from one population must be separable from animals from another population with an accuracy of at least 70%. That is to say that the investigator must be able (using the criteria mentioned in 1, 2, and 3) to identify the population from which a sample of animals has been taken, at least 70% of the time.

DESCRIPTION OF STUDY AREAS

Pocket gophers occur in three geographically separate areas of Alberta (see Fig. 5) which were divided, for reasons to be discussed later, into eleven sampling areas (Fig. 2). The three geographic areas are described below.

Figure 2. Map showing locations in which pocket gophers were trapped in the summers of 1966 and 1967.

1. Crowsnest Pass
2. Edmonton
3. Ministik Lake
4. Thorsby-Leduc-Camrose
5. Wainwright-Provost
6. Cypress Hills-Orion
7. Medicine Hat-Empress
8. Calgary-Cochrane-Turner Valley
9. Elbow Falls-Moose Mountain
10. Gorge Creek
11. Waterton-Lethbridge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scale
0 20 40 60 80 100
miles
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1
11
6
49°N

Crowsnest Pass

The Crowsnest Pass (Area 1, Fig. 5) is in southwestern Alberta. This is a high valley through which the Crowsnest River flows east out of Crowsnest Lake. The valley floor rises from 4000 to 6000 feet above sea level, is about one mile wide and laterally becomes steep, mountain slopes which are covered with coniferous trees.

This is one of the lowest passes through the Rocky Mountains. Frequent 'chinooks' and a high yearly snowfall (80 inches) typify the region. The soils have not been extensively studied but the elevation and steep topography have not lent themselves to extensive soil development and accumulation. The soils are 4 to 20 inches deep in the valley, but seldom exceed eight inches on the higher slopes that are often inhabited by pocket gophers. Most of the floor of the valley is cultivated land, while the sides are mixed forest and meadows heavily grazed by cattle (*Box taurus*) and elk (*Cervus canadensis*). Pocket gophers are found both in the valley floor, and the sides of the valley up to alpine elevations (app. 7300 ft.).

Edmonton-Calgary Region

The central area in which pocket gophers are found in Alberta varies greatly in topography. (Area 2, Fig. 5).

The general topography is that of hummocky-moraine plain from 2000 to 4000 feet above sea level. The area

varies from mixed wooded and rolling foothills in the west, to cultivated grainland interspersed with sandhills, ponds, and lakes in the east. The two major vegetation zones are 'aspen parkland' and 'boreal subarctic forest' (Bird, 1961). The organic soils of the extensive muskegs in the boreal forest probably prevent pocket gophers from expanding their range to the north.

Soil types vary from dark brown in the south to grey wooded and black in the north. The parkland of the central region is composed of grasslands on brown soils which have been invaded by woodlands, mostly of a deciduous nature (Bird, 1961). The soil is 12 to 14 inches deep. The southwestern edge of this area comprises foothills with dark grey wooded soils, 10 to 12 inches deep. The annual rainfall is 12 to 20 inches and a layer of undecomposed litter is found on the surface of the soil.

The land is used for two types of farming. Grain is grown in the central and eastern regions while in the south and west cattle farms are dominant.

This area includes most of the different topographic and vegetative types inhabited by pocket gophers of Alberta.

Medicine Hat-Cypress Hills

This region (Area 3, Fig. 5) is divided into two ecological zones which are discussed separately.

The larger of the two zones is the very dry land that

surrounds the city of Medicine Hat. This area extends from just west of Medicine Hat to the Saskatchewan border, and from 20 miles north of Medicine Hat to the 49th parallel of latitude, excluding the Cypress Hills.

It is semi-arid, with an annual rainfall of 11 to 13 inches; its soil is only about 5 inches deep. Hot dry winds cause a high rate of evaporation. The area is dominated by short grass prairie on brown soil, that under natural conditions, supports mostly grasses (*Gramineae*), sage (*Artemisia*), and cactus (*Opuntia*). Irrigation and the extremely long frost-free period allow farmers to practice truck farming, which provides ideal pocket gopher habitat. The highest pocket gopher densities in Alberta were found in irrigated fields and near creeks and ponds.

The other ecologically distinct area of the Medicine Hat region is the Cypress Hills zone. These hills rise as an abrupt escarpment from the prairies 40 miles south-east of Medicine Hat. They extend to a flat plateau, 1800 feet above the surrounding prairies, and have an area of approximately 1000 square miles, one third of which is in Alberta.

Rainfall is approximately 14-17 inches per year, but the area lacks the hot drying winds found on the surrounding prairies. This extra moisture and temperatures 10 degrees cooler than on the surrounding prairies have allowed mixed forest to become established as the dominant plant cover.

The soils of this region consist of a 3 to 6 inch surface layer of black soil, with the next 6 inch profile consisting of dark brown soil. The soil is fertile and on steep north facing slopes supports mostly forest. The top of the plateau supports a mixture of forest and grassland. The forest consists of lodgepole pine (*Pinus contorta*), white spruce (*Picea glauca*), and aspen poplar (*Populus tremuloides*). The grassland consists mainly of fescues (*Festuca*), blue grasses (*Poa*), and wheat grasses (*Agropyron*).

Ranching is the only form of agriculture carried out in this area and grazing pressure by elk, deer (*Cervus*) and domestic cattle is high.

The general ecological conditions in the north-facing slope of these hills are fairly similar to those found in the spruce-fir slopes of the Crowsnest Pass area 200 miles to the west (Bird, 1967). Thus, the Cypress Hills are an ecological island surrounded by prairie grasslands.

MATERIALS AND METHODS

Materials

Specimens

The specimens used in this study were borrowed from

museums or trapped by the author. Of 422 adults studied, 274 were females and 148 were males. Most of the above mentioned specimens were collected during the summers of 1966 and 1967.

Museum specimens were borrowed from the collections of three universities. The University of Alberta supplied 55 specimens; others were obtained from the University of British Columbia (3) and the University of Puget Sound (15). Specimens borrowed from the University of Puget Sound were those upon which Johnstone (1954) based his description of the subspecies *T. t. cognatus*.

As standard museum specimens consist only of a skull and a skin, I was unable to measure all characters used in this study on such specimens.

Methods

General

The method used was to compare samples of populations from different parts of the range of the species in Alberta to determine the degree of similarity in morphological characteristics.

I treated the samples as if they were from discrete populations and equally different in all ways from each other.

Distribution

Detailed knowledge of the distribution of pocket gophers

in Alberta was essential to the study in order to set up sampling areas and to assess possible relationships between adjacent populations. Since local authorities had postulated that the range of the pocket gopher was expanding, it was necessary to map the distribution as it existed in 1966 and 1967. Two basic methods were used to determine the current distribution of pocket gophers in Alberta.

First, field trips were made to all parts of the range of pocket gophers. Wherever possible the District Agriculturalist and local representative of the Fish and Game Division were contacted. Through these contacts and personal observation I plotted the distribution of pocket gophers.

Second, I sent a questionnaire (Appendix II) to all District Agriculturalists, agricultural field men, and pest control officers, asking them for information concerning the distribution of pocket gophers within their districts.

Field Collections

Pocket gophers were caught in Macabee traps (Miller, 1966) set in each of the 11 regions shown in Fig. 2. Trapping was continued until 25 animals of each sex were caught or until returns fell to near zero. Each area was trapped twice--once early in the summer and once near the end of the summer.

Preparation of the Material for Study

Trapped pocket gophers were either frozen or examined immediately. Frozen animals were brought to Edmonton and examined in the laboratory. The examination consisted of taking external measurements of the animal and then removing and preserving the skin, skull, vertebral column, and the right femur, tibia, fibula, humerus, radius, ulna, and scapula. If the specimen was a male, the baculum was removed. A sample was taken of parasites found during the examination and was preserved in glycerin-alcohol for further study by Dr. J.C. Holmes of the University of Alberta. Skeletons were air-dried in cheesecloth wrappings, brought to Edmonton, and placed in a colony of beetles (*Dermestes vulpinus*) as suggested by Anderson (1964). When the skeletons were clean they were placed in a ten per cent solution of hydrogen peroxide for bleaching. This also destroyed any dermestid eggs or larvae remaining in the skeleton. After bleaching, the skeletons were air-dried for at least 7 days before being measured.

The skins and skeletons of all animals trapped by the author have been placed in the Vertebrate Museum of the Department of Zoology, University of Alberta.

All data used for this study were obtained from adult animals. An animal was considered to be an adult if the pubic symphysis was split (females), if the baculum was completely ossified (males), or if the reproductive

organs were swollen and active. In a few cases I was unable to classify an animal by these criteria. I then plotted the length and weight of all animals in a sample on a graph. The points fell principally in two clusters--adult and sub-adult. If the unknown specimen fell into the adult grouping it was included in the study. If the unknown did not clearly fall into the adult group it was excluded from the study.

Characters

Sokal and Sneath (1963) stated that characters for study should be selected at random. However, the characters chosen for this study were those found to be repeatably measurable within the accepted accuracy (discussed below) on a series of sample skeletons. A detailed description of these measurements is contained in Appendix III and Figs. 3-4.

Recording of Data

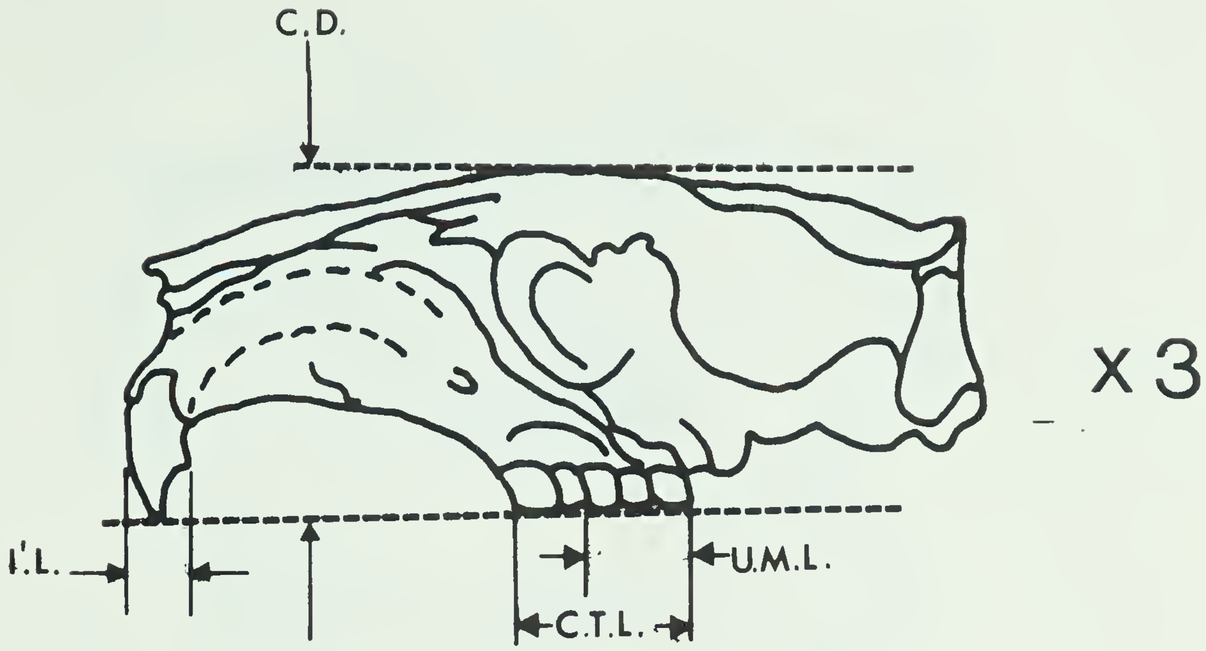
A data sheet was designed from which a keypunch operator could transfer the data directly to computer data cards. A program was written for an I.B.M. '360' computer which then performed the statistical analysis. As the data were expressed in millimeters and fractions thereof, I used a rule of thumb regarding accuracy, which states: "In the recording of any numerical value, sig-

Figure 3. Skull of *Thomomys talpoides* (Richardson).

3a. Lateral view of skull.

3b. Dorsal view of skull.

C.B.	Cranial Breadth
C.D.	Cranial Depth
C.T.L.	Length of Upper Cheek Teeth
F.N.L.	Fronto-nasal Length
I'.L.	Alveolar Length of Upper Incisor
I.W.	Interorbital Width
Ip.L.	Interparietal Length
Ip.W.	Interparietal Width
L.O.	Length of Orbit
N.L.	Nasal Length
R.W.	Rostral Width
U.M.L.	Length of Upper Molar Series
Z.B.	Zygomatic Breadth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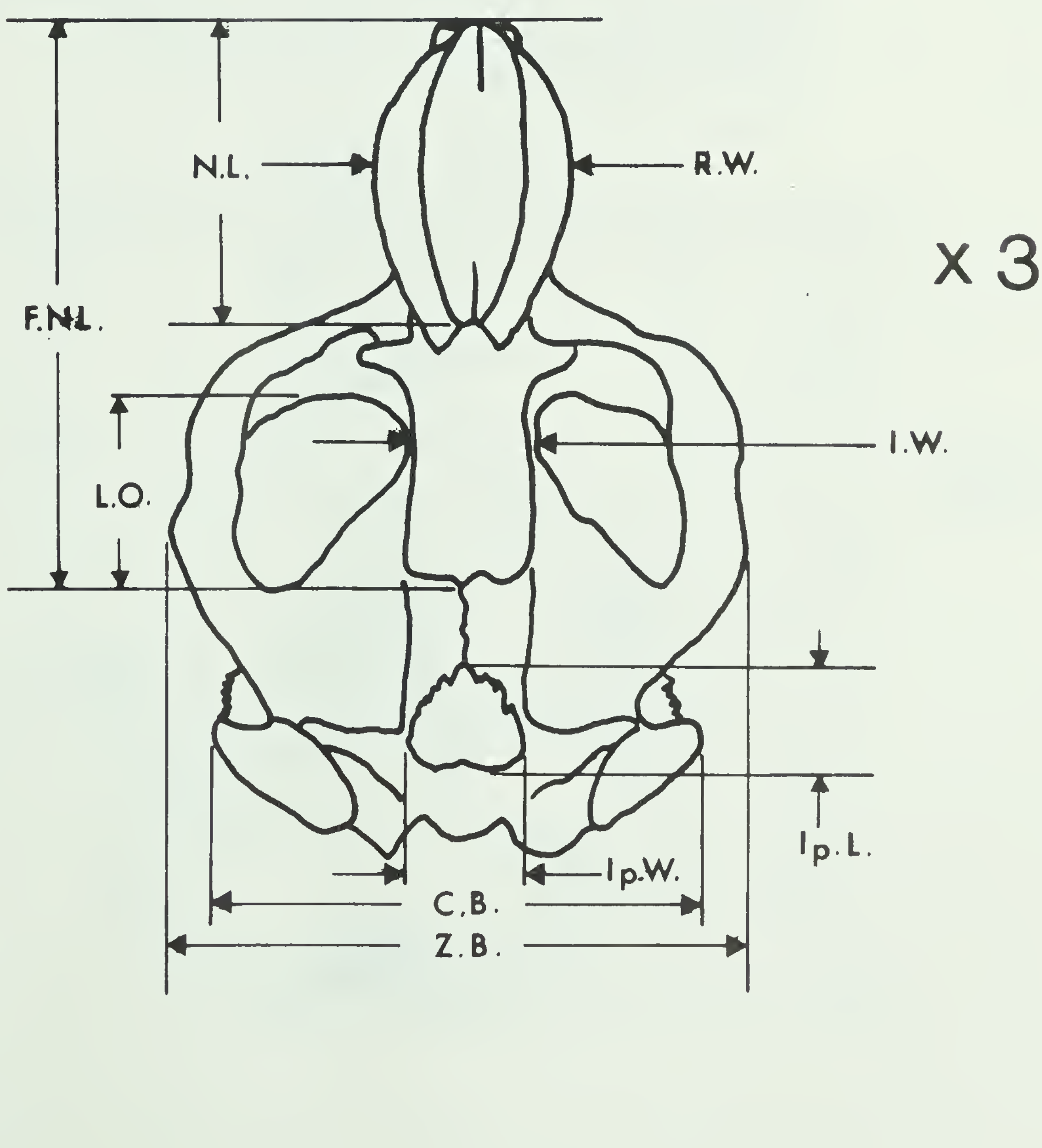
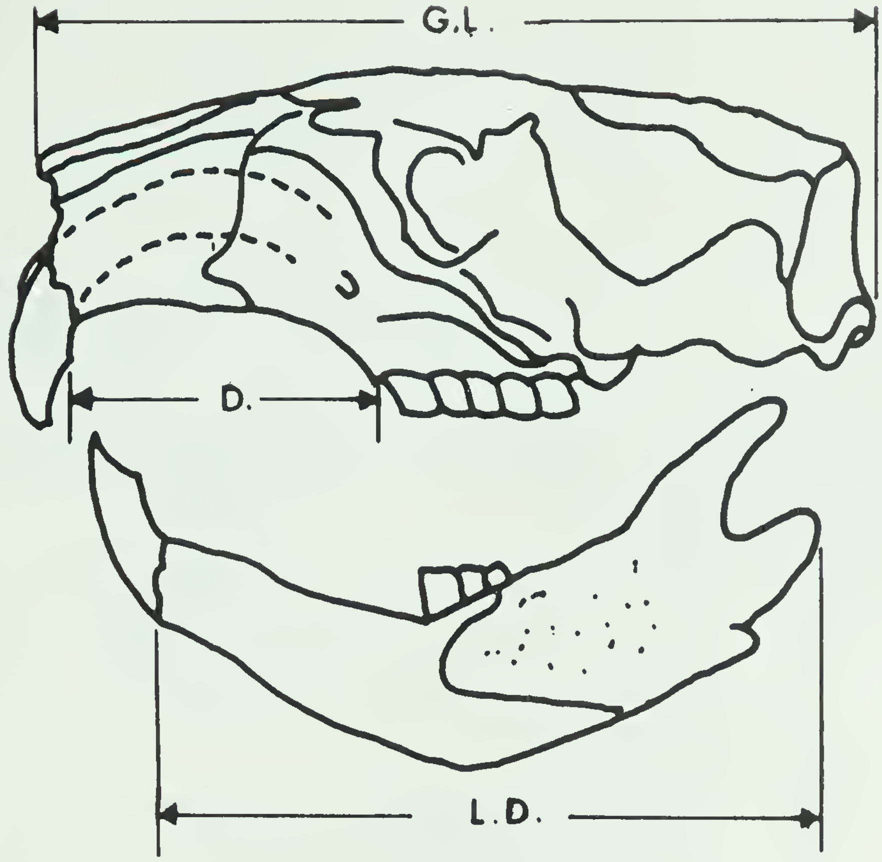

N.L.
R.W.
F.N.L.
L.O.
I.W.
Ip.L.
Ip.W.
C.B.
Z.B.
x 3

Figure 3. (continued) Skull of *Thomomys talpoides* (Richardson).

3c. Lateral view of skull and mandible.

3d. Ventral view of skull.

Bl.	Basal
BL.	Basilar
C.b.	Condylo-basilar
D.	Diastema
G.L.	Greatest Length
L.D.	Length of Dentary
M.W.	Molar Width
Pr.L.	Palatilar Length
Pt.L.	Palatal Length



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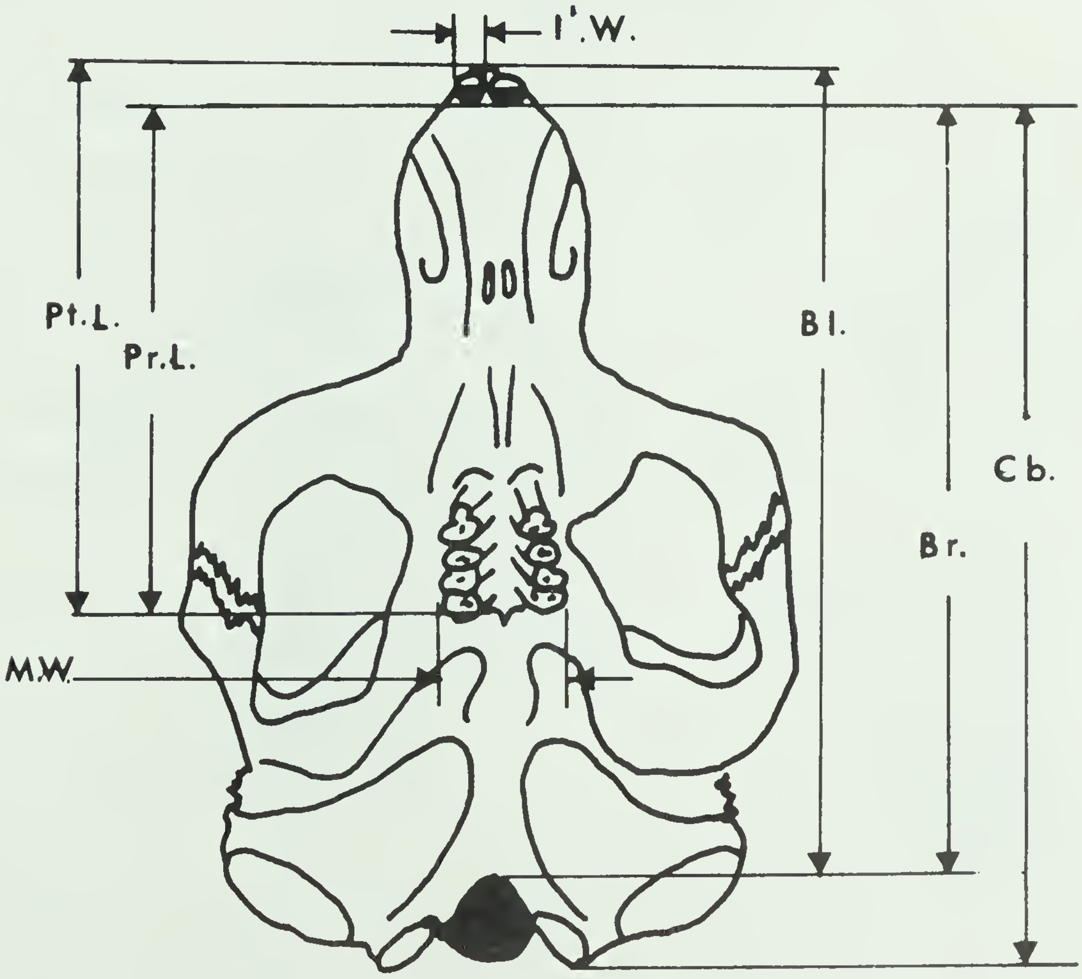


X3

Figure 4. Skeletal elements of *Thomomys talpoides* (Richardson).

4a. Lateral view of scapula

4b. Anterior view of scapula.

4c. Baculum

4d. Cranial view of humerus

4e. Caudal view of femur.

G.L.S. Greatest Length of Scapula

G.W.S. Greatest Width of Scapula

H.S.S. Height of Scapular Spine

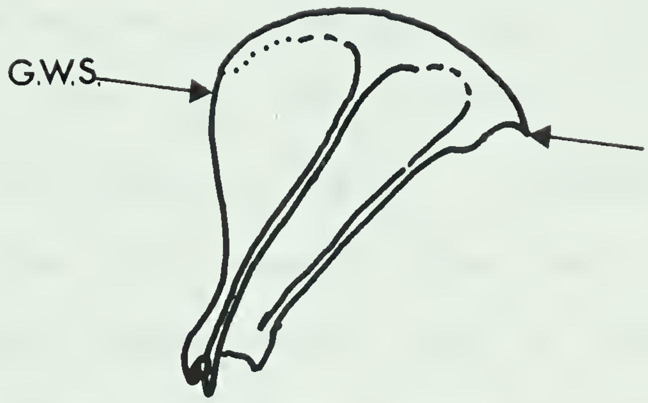
B. Length of the Baculum

S.D.F. Smallest Diameter of Femur

S.D.H. Smallest Diameter of Humerus

L.F. Length of Femur

L.H. Length of Humerus



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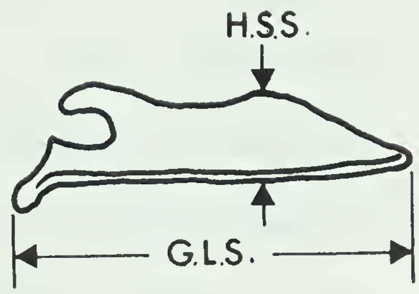

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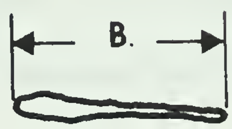

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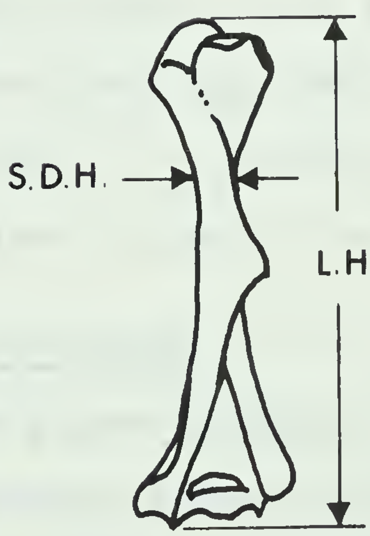

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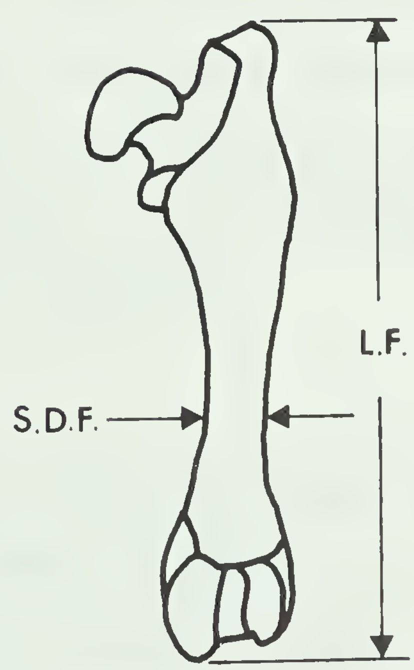


4e

nificant figures are, strictly speaking, those digits that are accurate; that is, the last digit is correct within half a step and thus implies a range within which the exact value lies. In a broader sense, one digit beyond these may be considered significant if it is nearer to the exact value than would be the first of the range implied by the preceding digit." (Simpson, Roe and Lewontin, 1960).

The measurements taken were, with some exceptions, the standard measurements used by mammalian taxonomists. The exceptions were measurements included to give more scope to the study and were often included subsequent to a trend being noticed during the preparation and examination of the specimens.

The number of vertebrae is an important character in the taxonomy of fishes but has not often been examined in mammals where it is assumed to be relatively constant. This count was included in this study to see how constant it is, and if it is not constant either within or between populations to use it as a taxonomic character.

<u>Colour of Pelage</u>

The pocket gophers used in this study more often than not displayed a non-uniform pelage colour often having dorso-ventral shading and/or a series of moult lines. Therefore, I decided to use a standard area, 2 inches square lying mid-dorsally at the level of the scapula, from which to judge pelage colour. Six specimens which could be distinguished from each other by colour were

chosen as representative 'types'. A 2-inch square was then removed from the standard area and each was assigned a value from 1-6 with number one being the lightest in colour and six the darkest. The standard area of all other specimens was then compared to these type squares and given a colour value. In specimens having a moult line through the standard area, the fresh pelage was compared to the type squares to give a value. The colours of the type squares was determined by comparison with Ridgeway (1912), and the squares are deposited in the Vertebrate Museum of the Department of Zoology, University of Alberta.

Treatment of Data

The computer was programmed to calculate and print out the following parameters for measurements; mean, standard deviation, standard error, range, and coefficient of variation. A Students' "t" test (a test of significance) was used on all data. Data from different sample areas were taken as being significantly different at the 5% level (95% confidence level) in most cases. Throughout this thesis, data of this level of significance will be referred as either significantly different from or not significantly different. For selected characters the computer also yielded values for ratios, which received the same statistical treatment as the other data.

RESULTS

The data presented in this section can be classified into four general types: non-measured data, measurements of external characteristics, osteological character measurements, and ratios (indexes of two characters). These data have been selected, for presentation, from all the other data for two reasons. I have presented one or more of each type of data, selected to give a fair and representative sample of all the data studied and to give representative dimensions of the animal in the type of measurement used. All the data used in this thesis are on deposit in the Department of Zoology, University of Alberta.

Non-measured Data

Distribution

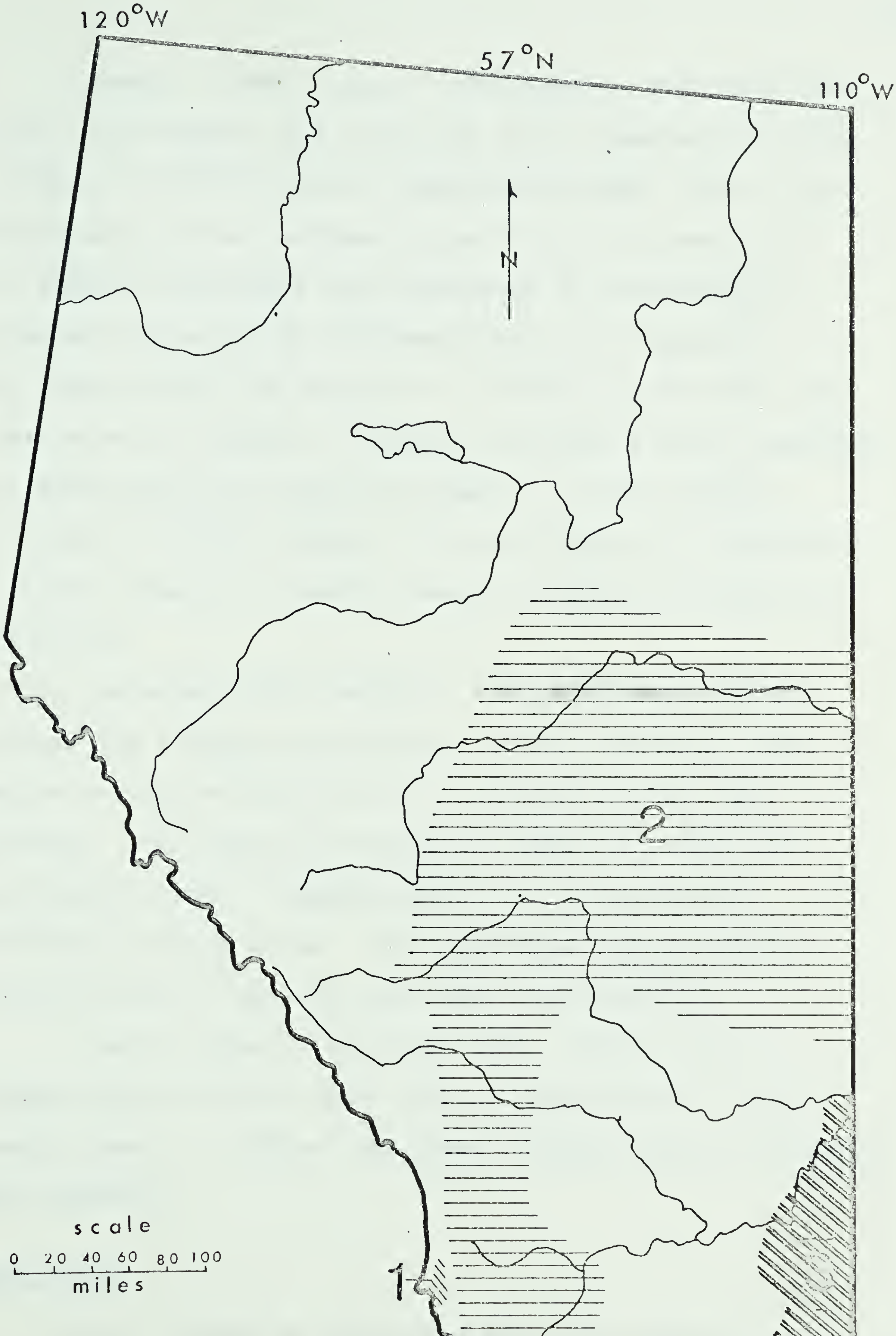
A detailed map of the distribution of pocket gophers in Alberta (Fig. 5) was plotted using the data from the questionnaire and personal observations. This map clearly indicates that the species *Thomomys talpoides* is restricted to three distinct areas in the southern half of the province of Alberta.

Sample Size

One aim of this study was the determination of an adequate sample size for taxonomic work involving small rodents, and hopefully, small mammals in general.

Figure 5. Map showing occurrence of pocket gophers in three geographically isolated areas of Alberta.

1. Crowsnest Pass
2. Calgary-Edmonton Region
3. Medicine Hat-Cypress Hills


120°W
57°N
110°W
N
2
scale
0 20 40 60 80 100
miles
1
49°N

Snedecor (1948) states "Investigators are often content with samples less than 0.1% of the population, while a sample of 10% is usually considered large. Such loose statements can be replaced by more definite ones only if there is available some knowledge of the mean and standard deviation of the population to be samples." He then derives the formula $n = t^2c^2/p^2$ by which one can determine the number of randomly selected animals necessary to approximate the population mean. In this formula n = No. of animals needed, c = coefficient of variability, $t = 2.6$ (from a "t" table), and p = probability value of 3% or 5%.

I selected 'Total Weight', the measurement which showed the greatest variability, as the character from which to use the coefficient of variability for this formula. The size of an adequate sample was then calculated for the 11 sampled areas, all of which had different sample sizes. The calculated values for 'n' varied from 3 to 25 with the mean value being 15.

I would suggest that these data indicate that a sample size of 25 (of each sex) is adequate for a taxonomic study. In 65% of the cases a sample size of 15 would be adequate.

Sex Ratio

Table I shows an unbalanced sex ratio which is

Table 1. Sex Ratios of Trapped Pocket Gophers.

Area No.	Location	n	% Males
1	Crowsnest Pass	77	29
2	Edmonton	80	46
3	Ministik Lake	18	44
4	Thorsby-Leduc-Camrose	34	29
5	Wainwright-Provost	59	25
6	Cypress Hills-Orion	84	35
7	Medicine Hat-Empress	9	44
8	Calgary-Cochrane-Turner Valley	24	38
9	Elbow Falls-Moose Mountain	18	39
10	Gorge Creek	14	50
11	Waterton-Lethbridge	8	33
	Total	425	Average 38%

significantly different from the 1:1 expected at conception. A 1:1 ratio may in fact occur; however, in this study the ratio of trapped animals was 1:1.8 which is different enough to warrant discussion. This unbalanced ratio may be due to one or more of the following:

1) The sex ratio at conception may not be 1:1 as in the case of *Myopus schisticolor* (Kalela and Oksala, 1966). However, there is no evidence of this in the literature of *T. talpoides*.

2) The unbalanced sex ratio could be the result of differential trapping success in favour of females. Howard and Childs (1959) state that male and female pocket gophers of the genus *Thomomys* are equally susceptible to trapping. If true, this would rule out this explanation.

3) Environmental selection against males could produce a differential survival rate and thus produce an unbalanced sex ratio. This selection could be in the form of high predation during emigration and travelling movements associated with breeding. Howard and Childs (1959) also stated that males are territorial and tend to be intolerant of their own sex especially during the breeding season. Thus subordinate males could be forced to occupy marginal habitats where they may be more susceptible to predation.

External Characters

Total Length

From Figure 6 it can be seen that male pocket gophers are, on the average, larger than females. In Alberta they average 7 mm larger than females. Animals from Crowsnest Pass (Area 1) are significantly different from all other populations included in this study. The next shortest animals are from Gorge Creek (Area 10). The males of this area are significantly different from the longest males examined which were from Ministik Lake (Area 3). The corresponding females, however, were not significantly different.

Total Weight

As shown in Figure 7, male Alberta pocket gophers are, on the average, heavier than females. They average 19 grams heavier than females. The range of this measurement, both within and between groups, is large and displays the greatest individual variability of any external character. The population from the Crowsnest Pass (Area 1) was significantly different from the population with the next lightest weight (Area 6). Females from Areas 6 and 11 are significantly different from all other areas at the 10% level, but only from Area 1 at the 5% level. Males from Medicine Hat-Empress (Area 7) are significantly different from all other areas except Area 3. Females from Area 3 are significantly different

Figure 6. Variability in total length of pocket gophers from different areas in Alberta. Locations of numbered sample areas are shown on Fig. 2. N = number in sample.

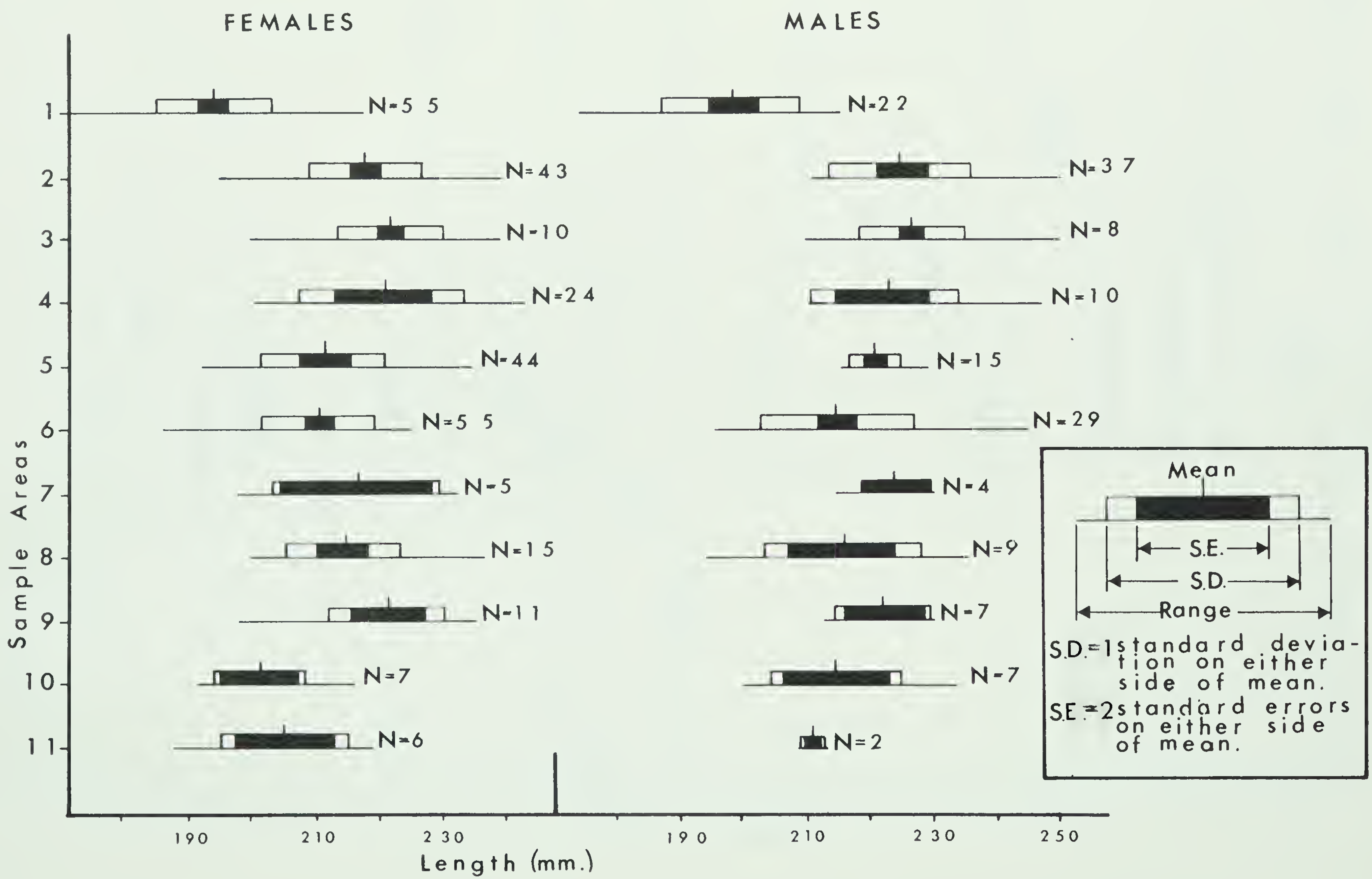
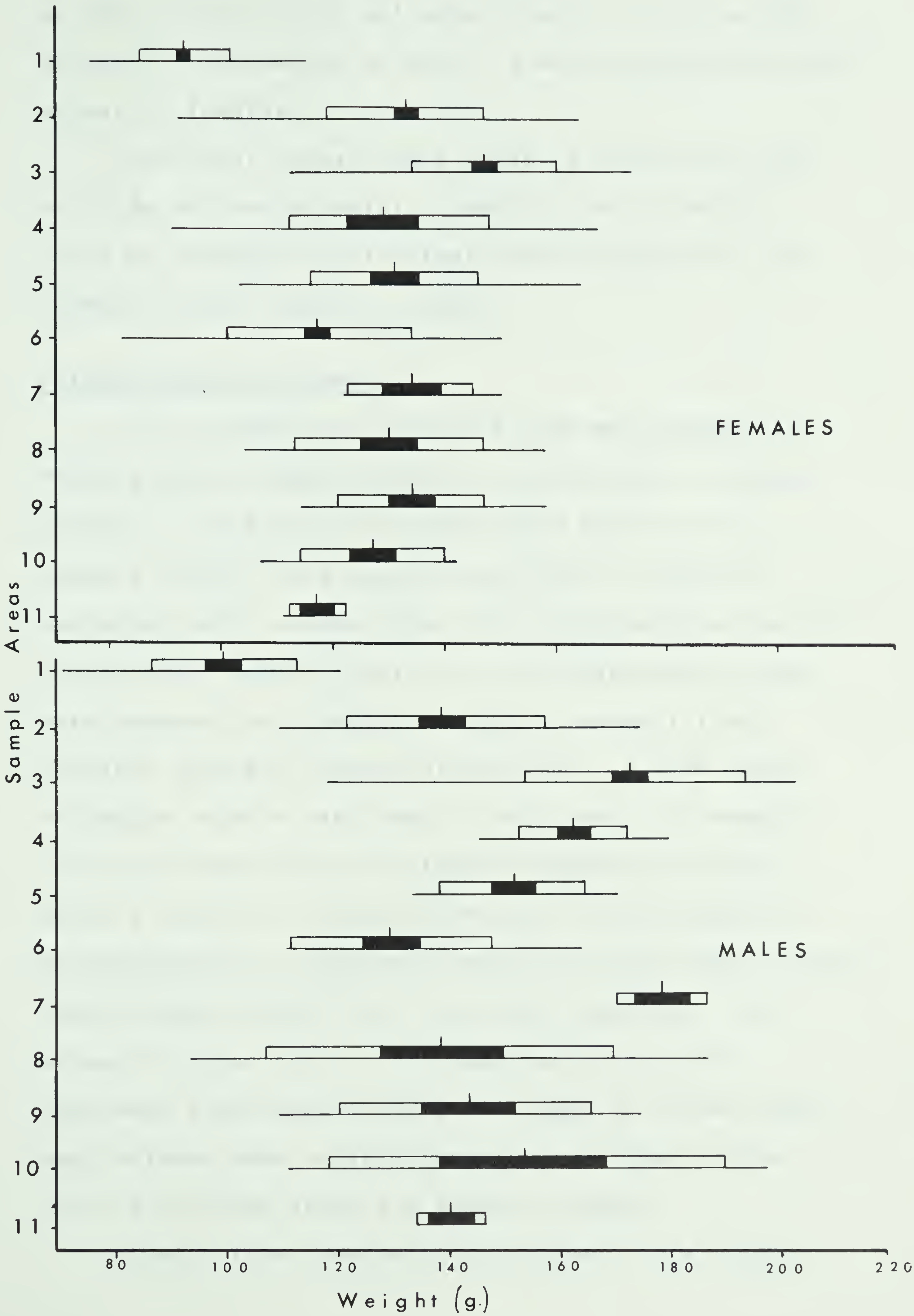

FEMALES
MALES
Sample Areas
1
2
3
4
5
6
7
8
9
10
11
N=55
N=43
N=10
N=24
N=44
N=55
N=5
N=15
N=11
N=7
N=6
N=22
N=37
N=8
N=10
N=15
N=29
N=4
N=9
N=7
N=7
N=2
190
210
230
190
210
230
250
Length (mm.)
Mean
S.E.
S.D.
Range
S.D.=1 standard deviation on either side of mean.
S.E.=2 standard errors on either side of mean.

Figure 7. Variability in weight of pocket gophers from different areas in Alberta. Symbols as in Fig. 6.


FEMALES
MALES
Sample Areas
1
2
3
4
5
6
7
8
9
10
11
80
100
120
140
160
180
200
220
Weight (g)

at the 10% level from all other areas, but not at the 5% level. The weight of males is more variable than the weight of females.

Individual animals were found to contain as much as 12.8g of food material. Some of the variability could be reduced if all animals were weighed with the stomach either removed or empty.

Pelage (Colour and Moult)

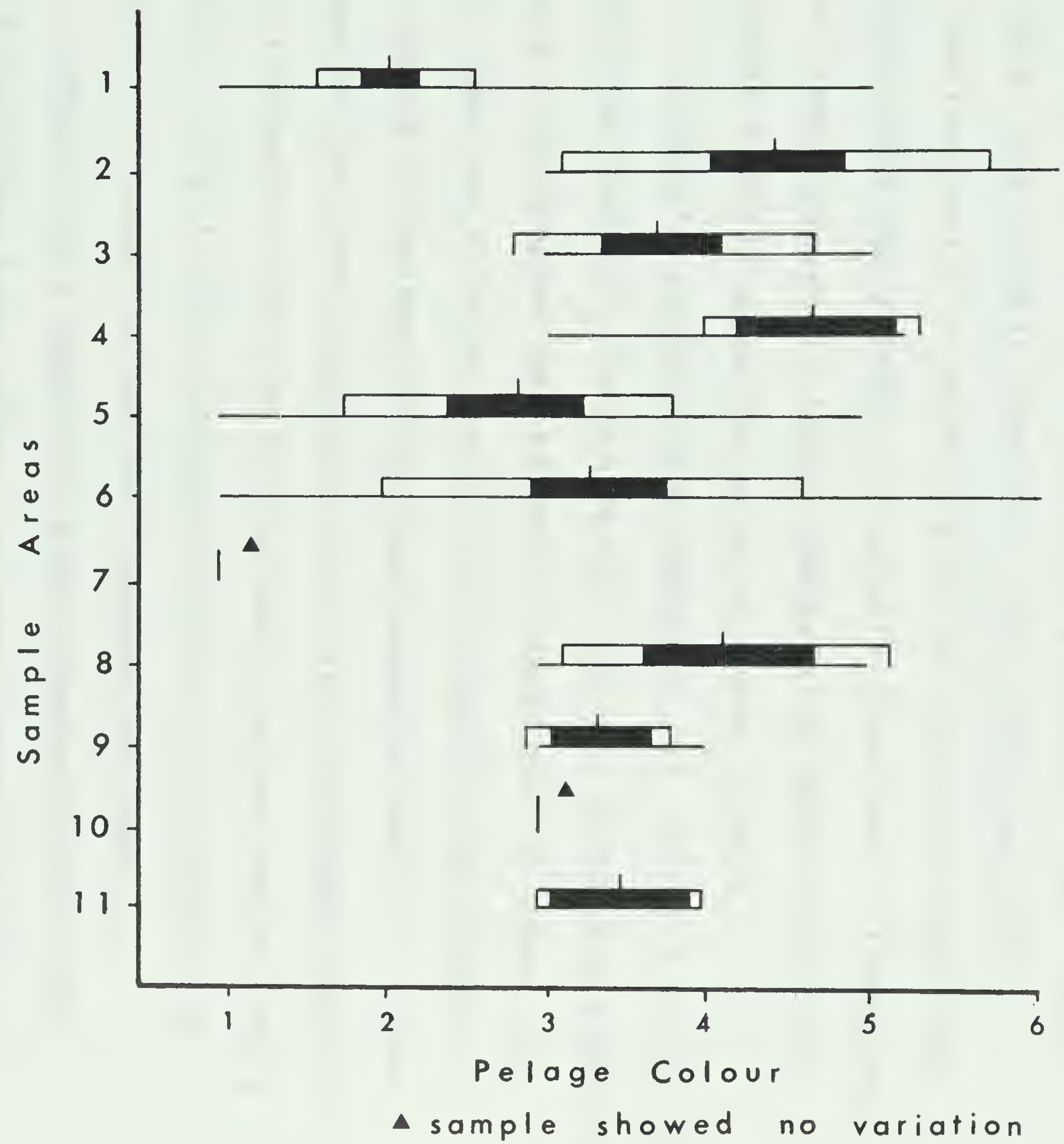
It is evident from Figure 8 that most groups of Alberta pocket gophers exhibit a wide range of pelage colours. The population sample from Medicine Hat-Empress (Area 7) and Gorge Creek (Area 10) show no variation but I suspect that this is probably a function of the small sample sizes. Soil and vegetation types were compared with pelage colours of animals from Ministik Lake and Cypress Hills-Orion. A wide range of pelage colours was found in each area, for example, in a cultivated field of alfalfa (*Medicago sativa*), which a series of transects and soil cores showed to be homogeneous in vegetative and soil type, where animals whose pelage varied from 1 to 6 were captured. The pelage of juveniles in this area varied from 2-6. Specimens from Areas 5 and 7 are light in colour which may indicate some correlation with soil type as the soils from these areas are light in colour.

Animals from Crowsnest Pass (Area 1) are rated a

Figure 8. Pelage colour (based on 2 inch standard patches graded 1-6). Males and females are both included in all samples. Symbols as in Fig. 6.

Pelage colours of type patches based on Ridgeway (1912).

1. Buffy brown
2. Saccardo's umber
3. Sepia
4. Olive brown
5. Clove brown
6. Dark neutral grey


Sample Areas
1
2
3
4
5
6
7
8
9
10
11
1
2
3
4
5
6
Pelage Colour
▲ sample showed no variation

value of 2 in Figure 8; however, this rating obscures the fact that the colour of the pelage of these animals has a very distinctive tone not found in other populations. Furthermore, about 66% of the animals from Crowsnest Pass had white patches, usually on the dorsal portion of the rostrum and along the mid-ventral line. About 35% of the animals from this area displayed a distinctive trait in which the entire lower jaw was white. This trait was evident in animals from Area 3 (Edmonton), but less frequently (8%). Melanistic (6 on the colour scale) animals occurred only in areas 3 and 6.

Juvenile animals from Edmonton (4), Cypress Hills (3), Medicine Hat (4), Turner Valley (2) and Crowsnest Pass (4) were live-trapped and raised to adulthood in captivity. Of these only the animals from Crowsnest Pass showed a change in pelage colour upon becoming adult. In the population from Crowsnest Pass juvenile pelage rated 3.5 on the colour scale while the adult pelage had a rating of 2. In all other areas no distinction between the colour of juvenile and adult pelage was seen.

Moult lines appear on pocket gophers soon after and sometimes even before the snow leaves the ground. Often several lines (up to 6) are visible on the animal at the same time. However, moult seems only to affect the luster of the pelage not the colour.

Number of Mammae

As shown in Appendix Ia, all the pocket gophers

of Alberta except those of the Crowsnest Pass have six pairs of mammae. These comprise two inguinal pairs, two abdominal pairs and two pectoral pairs. The population from Crowsnest Pass has only four pairs of mammae, two inguinal and two pectoral.

Osteological Character Measurements

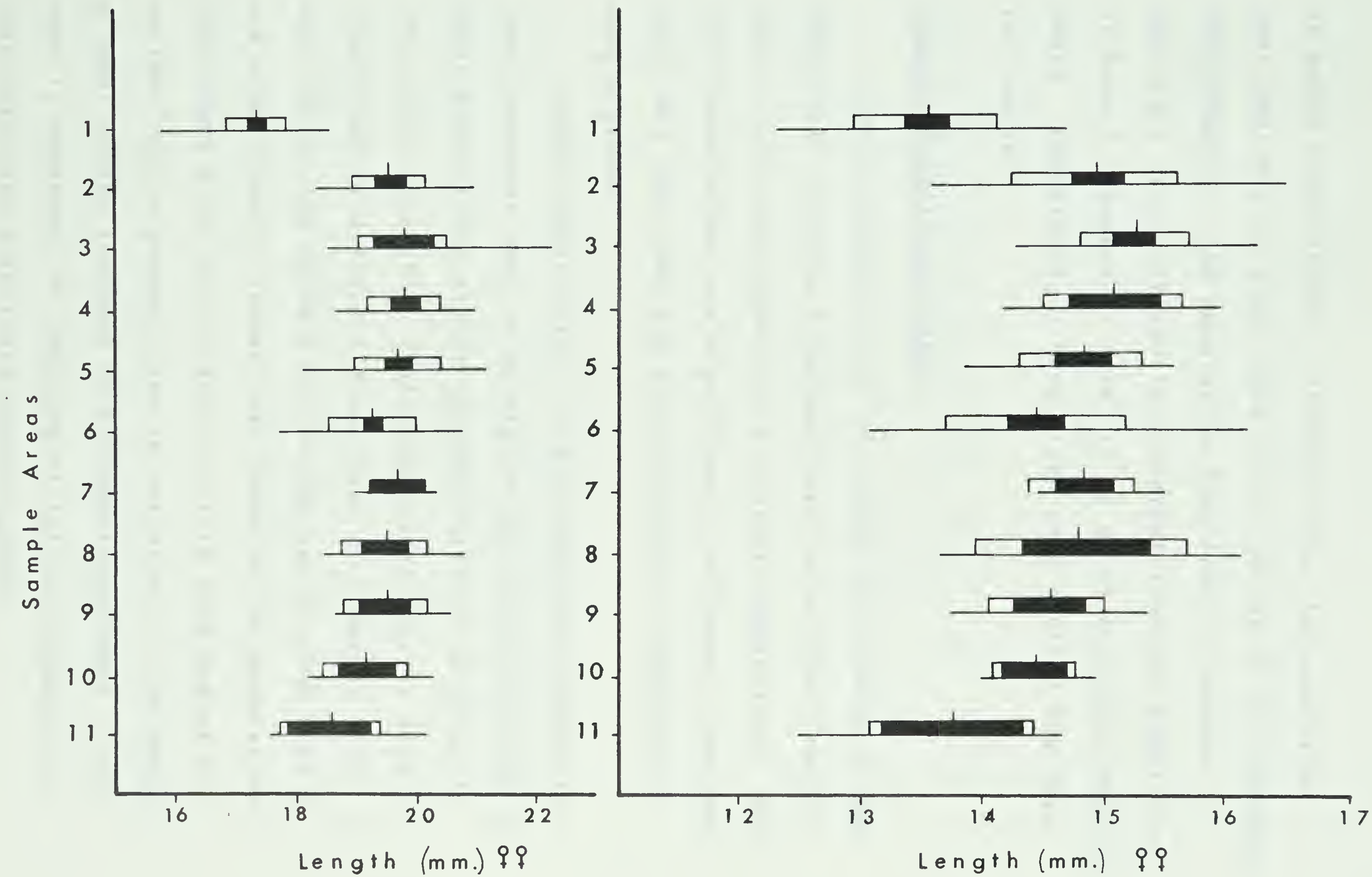
Condylo-basilar Length

This measurement, described in Appendix III, is often used in taxonomy as a measure of skull size and also as a base for several ratios.

The individuals comprising the population from Crowsnest Pass (Area 1) differ significantly from those of all other populations in this measurement (Fig. 9). The population from Area 11 (Waterton-Lethbridge) differs significantly not only from Area 1 but also from Areas 2, 3, and 4 as Area 6 differs from Areas 3, and 4, in the measurement of this character

In this and all other osteological characters mean values for males are higher than mean values for females but the rank orders as seen in Table 2 remain the same. These rank orders show Area 1 (the smallest animals) to be significantly different from Area 11 in 32 character measurements. The rank orders of Table 2 show the animals from area 1, which were the smallest in size,

Figure 9. Variability in condylo-basilar length of pocket gophers from different areas in Alberta. Symbols as in Fig. 6.



Sample Areas
1
2
3
4
5
6
7
8
9
10
11
16
18
20
22
Length (mm.) ♀♀
12
13
14
15
16
17
Length (mm.) ♀♀

as being significantly different from the population next smallest in size (area 11) in 32 out of 44 character measurements. The population from Area 11 (second smallest) is significantly different from the population of Area 3 (largest in size) in 14 of 44 character measurements. Henceforth, I have often only plotted the data for females.

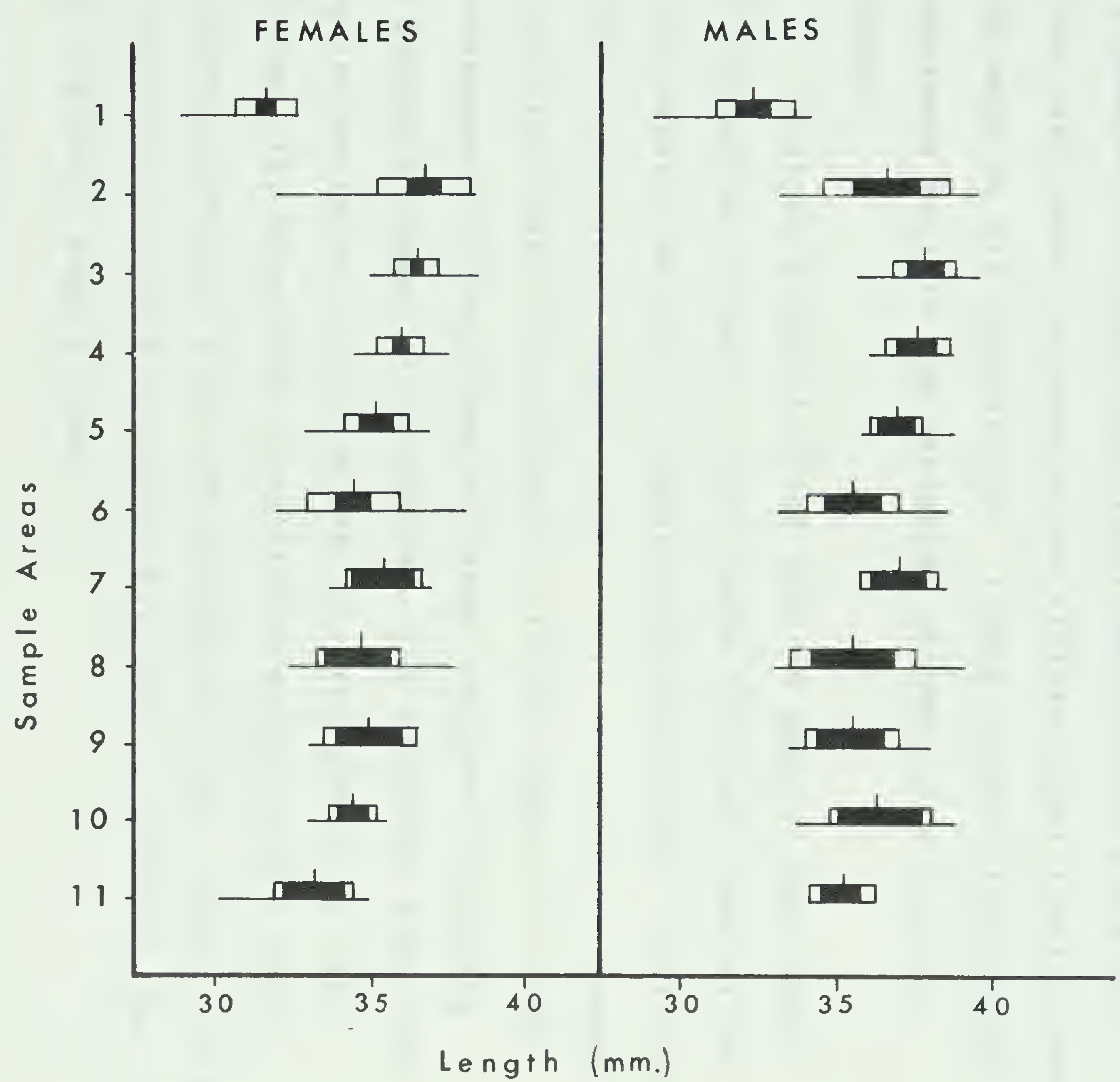
Cranial Breadth and Depth

Cranial breadth (Fig. 10) shows the animals of the population from the Crowsnest Pass to be significantly smaller than the animals of all other populations. No other populations are significantly different from each other and thus they may be considered to represent a single group.

Cranial depth (Fig. 11) also shows the population from Crowsnest Pass to be significantly smaller than all other populations except the population from Area 11. The latter population (Waterton-Lethbridge) is also significantly different from those of Areas 2, 3, 4, 5 and 7 while the animals of the population from Area 3 are significantly larger than those of the populations from Areas 6, 9, 10, 11 and 12. This high degree of variability is probably due to variation in the amount of wear on the incisors of different specimens. This wear is dependent on the type of soil and vegetation with which the animal had recent contact.

Figure 10. (Right) Variability in cranial breadth of female pocket gophers from different areas in Alberta. Symbols as in Fig. 6.

Figure 11. (Left) Variability in cranial depth of female pocket gophers from different areas in Alberta. Symbols as in Fig. 6.


FEMALES
MALES
Sample Areas
1
2
3
4
5
6
7
8
9
10
11
30
35
40
30
35
40
Length (mm.)

Number of Vertebrae

The number of vertebrae (Fig. 12) is not constant in any of the sample areas and the number of vertebrae in males does not differ significantly from the number in females. Although individual populations may differ from each other, no population differs significantly from the mean of all populations. I have no data from museum specimens because the vertebral columns were not preserved.

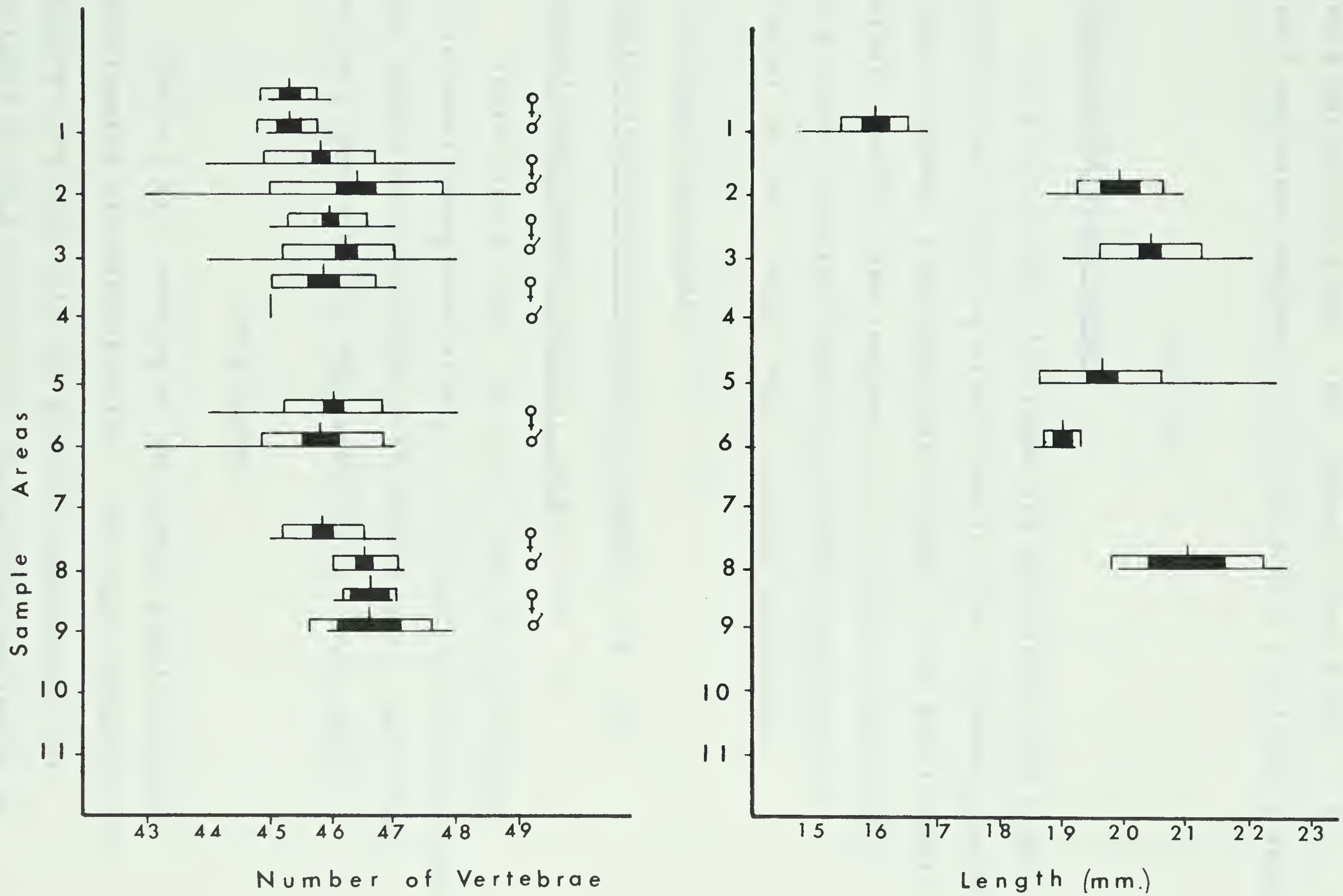
I was surprised to find that in general the number of vertebrae varied in individuals from each population. Only males from Area 4 showed no variation and I attribute this to the small sample size. All the variation seemed to be the result of variability in the number of caudal vertebrae with the other vertebral regions displaying a constant number of vertebrae. The Crowsnest Pass population exhibits little variability and generally less variability than other populations except Area 4 males. The males of Area 8 and the females of Area 9 show little variability in this character but this is probably due to the small sample sizes.

Length of Baculum

Figure 13 shows that males from Crowsnest Pass have a significantly smaller baculum than males from all other areas which seem to represent a single group. The mean of the largest population (area 8) is longer by 3.1 mm than the mean of Area 1 whereas the difference between Areas 6

Figure 12. Variability in vertebral counts of pocket gophers from different areas in Alberta. Symbols as in Fig. 6.

Figure 13. Variability in baculum length of pocket gophers from different areas in Alberta. Symbols as in Fig. 6.



Sample Areas
1
2
3
4
5
6
7
8
9
10
11
♀
♂
43
44
45
46
47
48
49
Number of Vertebrae
15
16
17
18
19
20
21
22
23
Length (mm.)

and 8 was only 2.0 mm. This suggests that Areas 2, 3, 5, 6 and 8 represent one population and Area 1 a different population.

RATIOS

Total Weight:Total Length

This ratio (Fig. 14) shows the population from Crowsnest Pass as differing significantly from all other populations. Animals from Area 3 are larger, and 6 and 11 smaller (significantly) than the mean of all groups except Area 1. This ratio indicates that the Crowsnest population is lighter per unit length than any other population.

Hind Food:Total Length (Fig. 15)

Cranial Breadth:Condylo-basilar Length (Fig. 16)

Cranial Depth:Condylo-basilar Length (Fig. 17)

These ratios (Figs. 15 to 17) show no significant differences among populations. All other ratios calculated also showed no significant differences among populations and have therefore not been presented in this thesis.

RANK ORDERS

Table 2 is a ranking of the sample populations by measurements of characteristics. For each characteristic measured the area with the greatest measurement was assigned a value of one with the ranking increasing to 11 as the character measurement decreased. In cases

Figure 14. Variability in the ratio 'Total Weight: Total Length' of female pocket gophers from different areas in Alberta. Symbols as in Fig. 6.

Figure 15. Variability in the ratio of 'Hind Foot: Total Length' of female pocket gophers from different areas in Alberta. Standard error not plotted; other symbols as in Fig. 6.

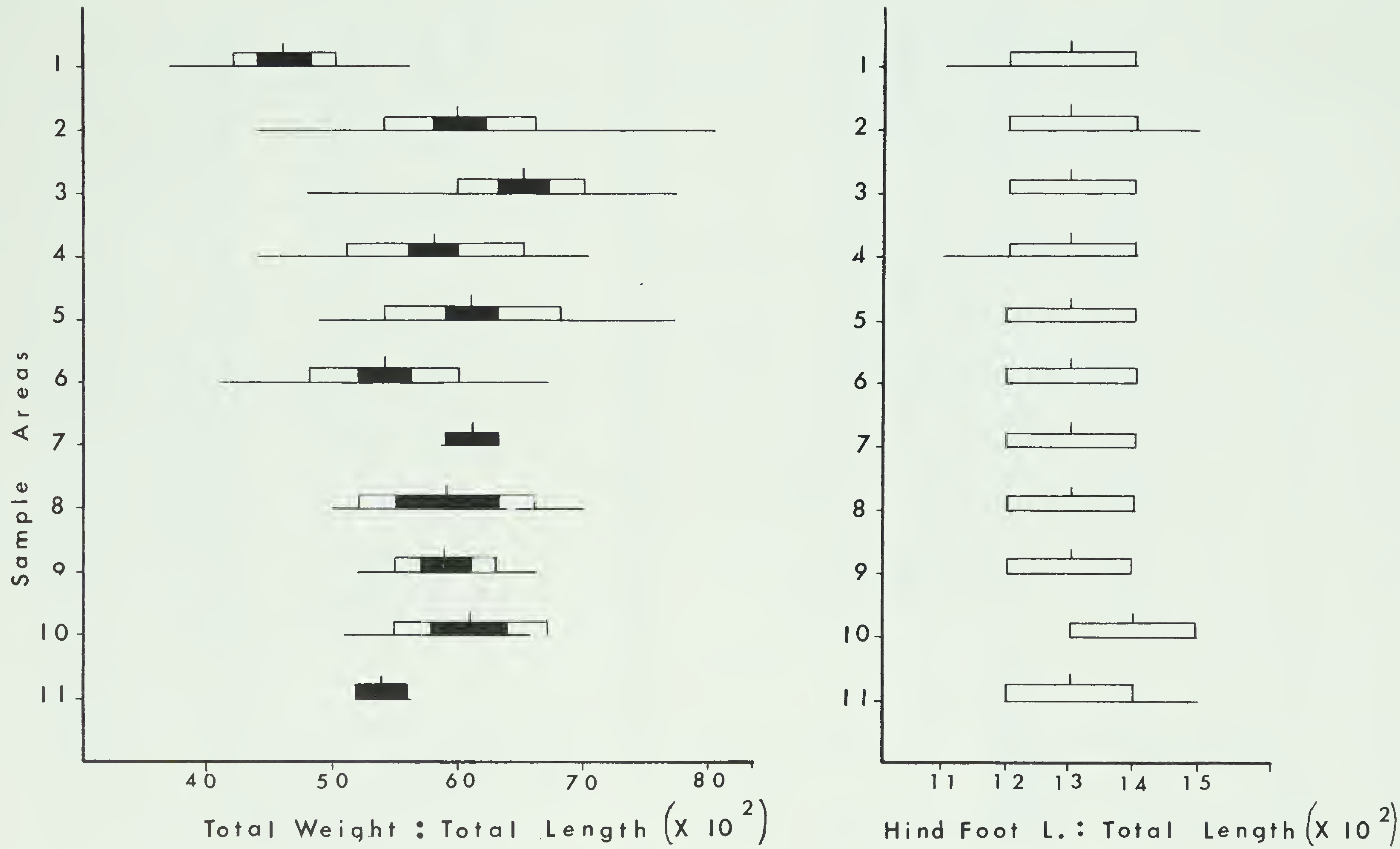
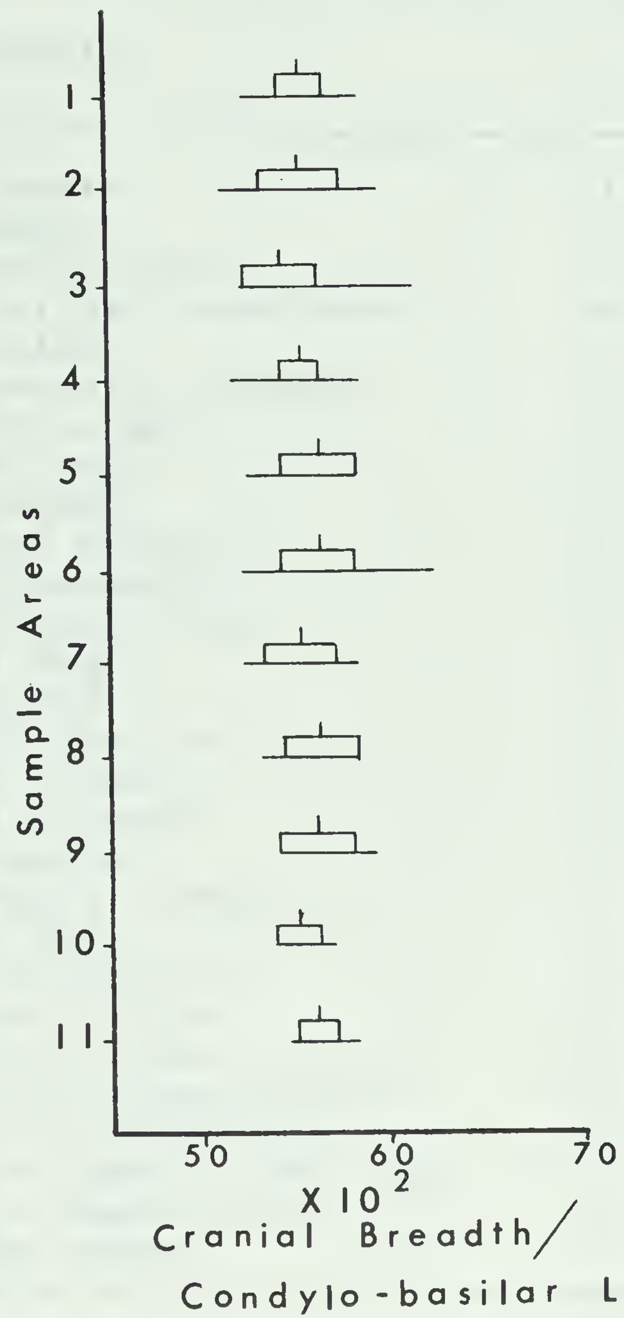

Sample Areas
1
2
3
4
5
6
7
8
9
10
11
40
50
60
70
80
Total Weight : Total Length (X 10^2)
11
12
13
14
15
Hind Foot L. : Total Length (X 10^2)

Figure 16. (Left) Variability in the ratio 'Cranial Breadth:Condylo-basilar Length' of pocket gophers from different areas in Alberta. Standard error not plotted; other symbols as in Fig. 6.

Figure 17. (Right) Variability in the ratio 'Cranial Depth:Condylo-basilar Length' of pocket gophers from different areas in Alberta. Standard error not plotted; other symbols as in Fig. 6.


Sample Areas
1
2
3
4
5
6
7
8
9
10
11
50
60
70
X 10^2
Cranial Breadth/
Condylo-basilar L.

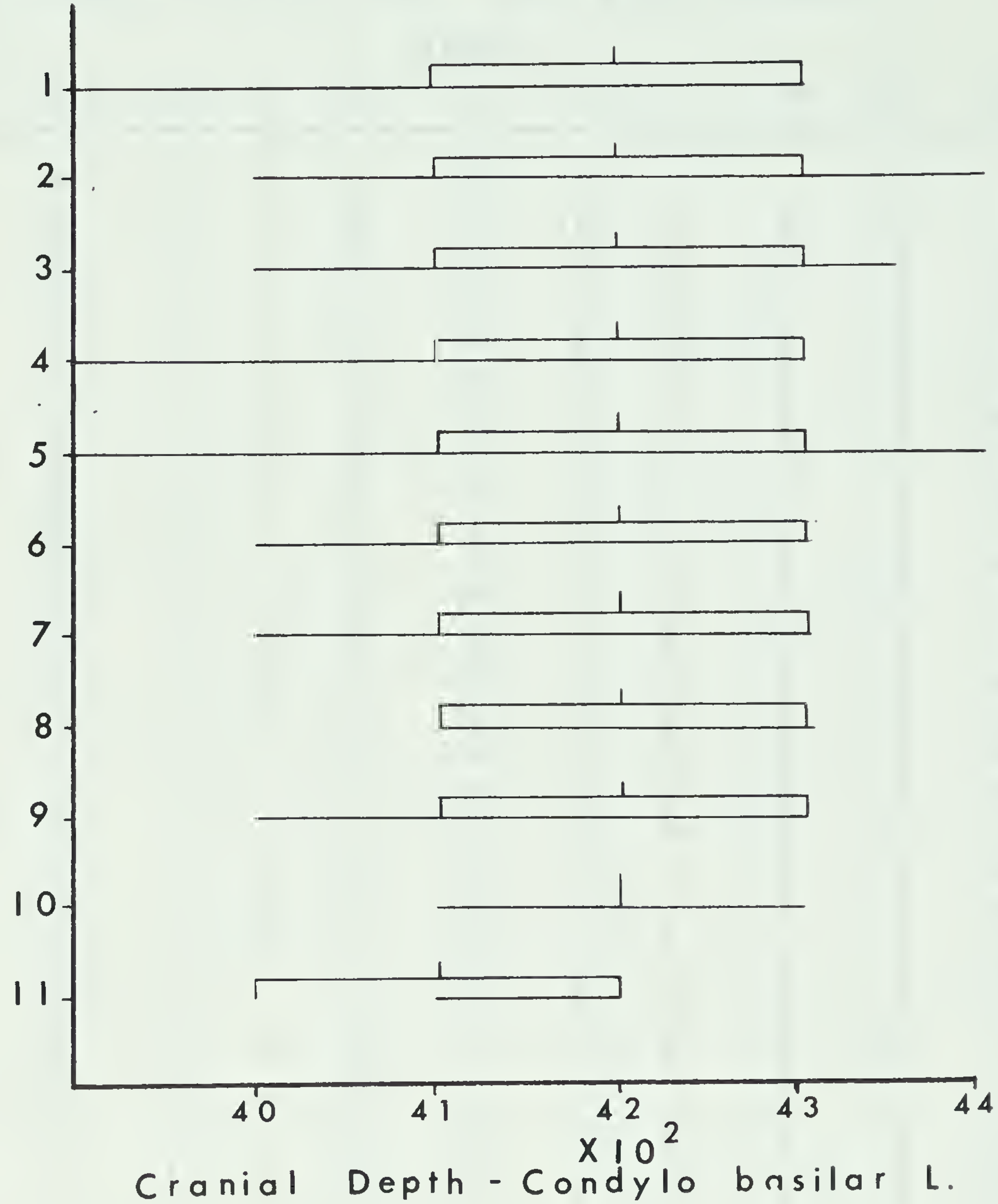

1
2
3
4
5
6
7
8
9
10
11
40
41
42
43
44
X 10^2
Cranial Depth - Condylo basilar L.

Table 2. Ranking Order, by Character, of Sample Areas (♀♀ only). Characters were ranked in size from greatest to smallest (1-11) with each area ranked.

Characters	Areas 1	2	3	4	5	6	7	8	9	10	11
Total Length	11	4	1	3	7	8	5	6	1	10	9
Tail Length	7	2	4	1	6	5	10	3	8	11	9
Hind Foot Length	11	2	4	1	7	10	2	5	2	9	7
Height of Ear from Notch	6	7	1	2	2	4	4	9	11	8	10
Total Weight	11	4	1	7	5	9	2	6	2	8	9
Condylo-basilar Length	11	1	2	3	5	8	4	7	6	8	10
Greatest Length	11	3	1	2	4	8	5	7	6	9	10
Basilar Length	11	3	1	2	5	9	4	7	6	8	10
Basal Length	11	3	1	3	6	9	5	7	7	3	10
Zygomatic Breadth	11	6	2	1	4	7	5	7	7	3	10
Cranial Breadth	11	5	1	1	3	8	3	6	6	9	10
Interorbital Width	11	6	4	2	1	8	5	3	7	10	8
Rostral Width	11	6	1	2	3	9	9	6	5	3	8
Molar Width	11	4	1	3	5	8	7	2	8	6	10
Depth of Cranium	11	3	1	2	4	8	5	6	7	8	10
Palatal Length	11	3	2	1	5	8	4	7	6	9	10
Palatilar Length	11	3	1	2	4	9	5	7	6	8	10
Nasal Length	11	4	1	1	3	7	5	6	8	10	8
Fronto-nasal Length	11	3	1	2	4	9	5	7	5	8	10
Orbital Width	11	2	1	3	6	9	5	7	4	8	10
Length of Dentary	11	3	1	2	5	8	4	6	7	9	10
Length of Incisor	11	8	2	4	1	7	2	8	6	5	10
Width of Incisor	11	6	4	2	4	8	7	9	9	2	1
Length of Interparietal	11	7	3	2	4	1	9	8	5	10	6
Width of Interparietal	1	10	11	9	8	3	7	5	4	6	2
Length of Upper cheek Teeth	11	3	1	5	2	10	8	6	7	4	9
Length of Upper Molars	11	3	1	6	2	9	9	5	7	3	10
Diastema Length	11	2	1	2	7	5	4	7	7	6	10
$\overline{X}$ =	10.3	4.1	1.9	2.9	4.4	7.5	5.3	6.3	5.9	7.4	8.8
			2.97			6.43			6.49		
			3.32								

of two areas having the same mean for any given characteristic, both were assigned the same rank and the next rank was deleted.

The data obtained from Table 2 can be used to show that the populations of pocket gophers in Alberta can be arranged along a cline. Animals from the Ministik Lake population are the largest while those from the Crowsnest population are the smallest with those from the Waterton population the next smallest. This means that the smallest animals are in the geographic southwest of Alberta and the largest animals are geographically north, (actually centre) with intermediate sized animals generally occupying geographically intermediate areas. Area 1 has the highest total rank order (smallest size). Area 11 has the second highest rank. However, the populations from these areas are significantly different in 32 characteristics. Area 3 has the lowest rank (largest size) but is only significantly different from Area 11 in the measurement of 14 characteristics.

One interesting point which becomes obvious from Table 2 is that interparietal length tends to vary inversely with interparietal width.

DISCUSSION

One of the aims of this research was the evaluation of characters to determine those most reliable and useful for use in taxonomic studies. The characters examined were of two types: external and osteological.

External measurements such as weight and length may be affected by such factors as abundance and type of food available, the length of time since last feeding and pregnancy. Others, such as length of hind foot may be affected by the soil type in which the animal is living and its abrasive effect on the claws, the length of which are included in the measurement of 'Hind Foot Length'. Thus, the same animal could have different external measurements at different times depending on how much food was in the gut or the type of soil in which he had recently been digging. Such measurements did, however, indicate that male pocket gophers are larger than females, a relationship that Hill (1937) reported for *Thomomys bottae*.

Pelage colour was extremely variable but no definite correlation was found between colour and either soil or vegetative type. Some correlation was suggested between the light colour of the populations from Medicine Hat and Wainwright and the light coloured soils of these regions. Juveniles caught in these regions had a colour range of 1 to 4, while the adult pelage colour of the Medicine Hat region (Area 7) had a value of one, which seems to indicate that adult pelage colour is the result of selection against all other pelage colours which might indicate that a light pelage colour is advantageous in an arid area such as that found around Medicine Hat.

Using the number of mammae as a guide, one is able to differentiate the population from Crowsnest Pass from all other populations. *T. t. fuscus*, the subspecies which

lies adjacent to *T. t. cognatus*, has the same mammary formula as the population from Crowsnest Pass. This might indicate that the origin of *T. t. cognatus* is from the west.

In general, external measurements proved to be highly variable and large ranges were the rule. The number of mammae and pelage colour were least variable, and both yielded a clear distinction between the Crowsnest population and all others.

The second type of data to be examined were measurements of the bones of the skull and other parts of the body. It was postulated that osteological characters are less affected by temporary environmental and physiological conditions, such as shortage of food and breeding condition of the animal, than are external measurements. I chose to use many more osteological characters than external measurements because of this assumed independence.

This type of measurement, as shown by Figs. 9 to 13, shows that male pocket gophers are consistently about 5% larger than females. This consistency, as opposed to the 5% to 15% difference found in external measurements, seems to indicate that osteological characters are less variable than external characters.

The number of vertebrae was found to be more variable within than between populations and thus was of no taxonomic value. The fact that the variability seemed to stem from an inconstant number of caudal vertebrae has

little significance except to say that it casts doubt on the use of 'Tail Length' as a good taxonomic character.

The baculum was found to be a character by which males from Crowsnest Pass could be separated from males of all other areas 100% of the time, however, using this character one could not separate males of Areas 2 to 11 from each other. The length of the baculum was found to be of the same proportion to 'Total Length' in all populations and thus must be considered a concordant character.

I calculated the combined mean of each osteological character for the populations from Areas 2 to 11. I then compared individual population means to the combined mean. Areas 2 and 11 (the largest and second smallest populations) seldom differ significantly from the combined mean while the population from Area 1 differs significantly from the population mean in all but three characters. These data indicate that the populations from Areas 2 to 11 represent a single large group and that the population from Area 1 (Crowsnest Pass) represents a second group. It is my feeling that these two groups represent subspecies.

Hill (1937) suggested that pocket gophers continue to grow until death. This growth leads to variability of direct measurements even within adults from the same environment as any given population may contain 1-, 2-, and 3-year old adults.

An age independent classification might be possible

if based on ratios rather than single measurements. The constancy of ratios seems to indicate that they are, in fact, age independent. Of the 20 ratios calculated, only one (Fig. 14) showed any difference between populations. Other ratios show no differences between populations, indicating that, although animals from different populations may be of different sizes, their proportions are the same. All populations exhibit the same body proportions and thus should be considered a single species.

The lower levels of variance and independence from temporary environmental conditions make osteological characters better taxonomic indicators than external characters. However, Lindroth (1967) states that it is important to emphasize that a measureable "character" of an individual organism cannot be regarded as a good character unless its independence from other characters is checked. Often the elongation of one appendicular bone such as a femur is likely to be associated with a similar change in another osteological character. This means that the measurement of both concordant characters really only duplicates the information which could have been obtained from just one measurement.

Most characters used in this study were found, after analysis, to be concordant. It was found that animals from all study areas had the same body proportions in both external and osteological characters.

Not all the characters used in this study can be

considered concordant. Colour and the number of mammae were found to be independent of the general growth trend (discordant). There is no correlation between size and the number of mammae or the pelage colour. There also was no correlation between pelage colour and the number of mammae.

Pocket gophers in Alberta are presently distributed in three geographically isolated areas. A possible explanation for this may lie in historical zoogeography. Alberta was covered by ice during the last great glaciation (Wisconsin), the second advance of which began about 35,000 years ago (Westgate, 1964). The entire province, except Cypress Hills, was covered by ice, and all animals were forced to move by the advancing ice. In post-glacial time, beginning about 10,000 years ago, there was a recolonization of Alberta. Two groups of pocket gophers likely entered Alberta: *T. t. talpoides* on the plains and *T. t. cognatus* in the mountain valleys. It is possible that two refugia were used, and that the two groups which entered Alberta are from different refugia. However, I suspect that the uniformity of body proportions in Alberta pocket gophers indicates that only one refugium was used. Alberta pocket gophers are therefore probably evolved from one stock of animals surviving in one refugium but dispersing on a two-pronged front, both moving in a northerly direction. The front which moved along the plains was able to move faster

than the one in the mountains and thus was the first to enter Alberta. Thus, from the time of leaving the refugium the two fronts were separated, with gene flow only occuring behind the fronts through the base population from which both fronts moved. This restriction of gene flow was probably impeding enough to allow the size, colour, and mammary differences present in the plains and mountain populations which occupy Alberta. *T. t. talpoides* has probably been present in Alberta for centuries but *T. t. cognatus* has only recently entered the province. The movement of *T. t. cognatus* over the Crowsnest Pass from British Columbia probably occurred in 1938 (Anderson, 1946).

The similarity of morphology of the present population from Medicine Hat to the population from the Calgary-Edmonton region may be explained by postulating a historic contact between the two populations along the valley of the South Saskatchewan River. The similarity of means in the ranking by characters (Table 2) may provide some evidence for this hypothesis in that it shows the combined means of these areas are similar. Other evidence which may support this hypothesis is the fact that biologists and agriculturalists from the Brooks area mentioned that a pocket gopher was recently caught near Brooks and that pocket gophers were often caught in the region of Dinosaur Provincial Park and adjacent areas of the South Saskatchewan River early

in the century. If the above is true, then I would suspect that these animals were remnants of a population which at one time occupied the entire valley. This population would have allowed gene flow between populations which then occupied the positions of the two present geographically isolated populations. However, I suspect that this isolation has been so recent as to have had a limited effect, if any, on the gene pool.

I suspected that small populations might differ morphologically from adjacent large populations with which they have minimal contact. If variation was found to occur, one might infer that it was the result of restricted gene exchange between populations. Populations from Areas 9 and 10 (Fig. 2) are peripheral populations connected to adjacent populations by approximately 30 miles of land that is only sparsely populated by individuals of small groups of gophers. It seems, after looking at all the data (Figs. 5-17) that the morphology of those populations is not measurably different from that of the population of Area 8. Table 2 shows Areas 9 and 10 to be similar to the adjacent large population of Area 8.

This could be for one or all of three reasons:

(1) Semi-isolation has no effect, and gene flow with the adjacent large population is as high as it is within the large population.

(2) Semi-isolation has an effect on the gene pool

but the environmental pressures in the two areas are not different enough to produce morphological change.

(3) The characters chosen do not reflect the changes in the gene pool.

I suspect this lack of difference is due to emigration, which keeps the gene pool constant between the two adjacent populations. Emigration and associated range expansion is illustrated by Alberta pocket gophers which have expanded their range from the south bank of the North Saskatchewan River (near Vermillion, Alberta) to a region 30 miles north of the river in approximately 20 years. This expansion was likely made possible by a small population crossing the river on ice, probably in the spring of 1951, the year the first population of gophers was noticed on the north bank of the river. In the past 3 years the pocket gophers have moved almost 2 miles a year north along Highway No. 2 leading to Peace River. This expansion of range indicates that exploratory movements occur in pocket gopher populations and this type of movement if it happened in Areas 9 and 10 could bring about enough gene interaction between scattered individuals to reduce to a minimum the differences between populations.

I suggest, therefore, that *T. t. andersoni* and *T. t. talpoides* are really a single northern subspecies derived from *T. t. bullatus* (see Appendix 1a). I also feel that

T. t. cognatus has split from *T. t. fuscus* rather than being a remnant population of *T. t. talpoides*. It seems presently as if *T. t. cognatus* is expanding its range in an easterly direction at a rate of about 1 mile a year. At this rate the two populations should meet in the near future. It will, at that time, be interesting to see if the ability to interbreed has been retained, and, if not, has a new species evolved? I would speculate that the difference in size and other characters will serve to isolate these two populations reproductively even if their ranges do come into contact.

Another aim of this research was the determination of an adequate sample size for a taxonomic study of small rodents. It is my feeling that all too often researchers collect data (and animals) in sample sizes which are too large. A sample size which is too large is a waste of animals and an unnecessary investment of the time and funds of the investigator. It appears that for my study a sample of 25 animals of each sex from each sampling area would have given a mean value which was within 3% of the mean for the population 95% of the time and in 65% of the cases a sample size of 15 would be adequate.

Finally I wished to evaluate the use of a computer as a tool in taxonomic studies. It is my feeling that a computer allows the investigator to work with more characters than would be practical if one had to use a

hand calculator. The computer offers programs which will do complete statistical tests on data in seconds rather than weeks or months required for hand calculating. However, data must be collected in a uniform manner and in a form which the computer can use or much time will be wasted preparing raw data for computer analysis. Basically, a computer offers speed to the taxonomist and an incredible amount of stored data which can be readily recalled for additional analysis.

CONCLUSIONS

I conclude that the geographically isolated population from Medicine Hat-Cypress Hills region named *T. t. andersoni* is not sufficiently distinct from *T. t. talpoides* to rate subspecific status. I think that these populations have only recently been isolated from each other by agricultural practices, and thus probably still have essentially the same gene pool.

I would also suggest that *T. t. cognatus* is sufficiently different from *T. t. talpoides* (i.e., fulfils subspecific criteria as stated) to be retained as a separate subspecies. Thus, my research indicates that there are only two populations in Alberta sufficiently distinct to be granted subspecific status: *T. t. talpoides* (Richardson) and *T. t. cognatus* Johnstone.

In the final analysis, it proved impossible to make a comparison of numerical and classical taxonomy because

only three independent variables (overall size, colour, number of mammae) were used in this study. However, the use of a computer, the standard tool of numerical taxonomists, greatly aided in the analysis of the measurements and ratios, and made possible the recognition of the fact that variation in almost all measurements is merely a reflection of variation in overall body size.

Interestingly, my results suggest that the methods of classical taxonomy as practiced by those who immediately preceded me in the study of Alberta pocket gophers came close to producing a defensible classification. My more comprehensive analysis has refined the system, rather than drastically modified it. It remains for those who follow to evaluate my conclusions in the light of additional characters such as serum proteins and karyotype.

SUMMARY

The taxonomic history of *Thomomys talpoides* in Alberta is extensive. According to Soper (1964) there are three subspecies in Alberta. I decided that "subspecies" is a valid and useful category, defined as a physically distinct population of a species differing from all other such divisions of the same species, and have based my final analysis on this definition.

Pocket gophers are found in three geographically

isolated areas in Alberta. This fact, according to my definition, allows only three possible subspecies. To determine the number of subspecies that exist, I used 422 animals and took measurements of 44 characteristics. I also calculated ratios based on these measurements. External characteristics were found to be highly variable and difficult to measure accurately. Osteological characters were less variable than external measurements. In this study, the use of ratios shows almost no difference between populations, which all seem to have the same body proportions and are therefore all of a single species. Analysis of 44 characters shows that there are only two subdivisions of this single species in Alberta. One group is from the Crowsnest Pass region (group 1) and the second comprises populations from the rest of Alberta (groups 2-11). Crowsnest Pass animals are different in pelage colour, number of mammae (four pair), and are small in overall size. I feel that these differences are sufficient to support the subspecific status of *T. t. cognatus* Johnstone (1954). Animals from Medicine Hat and Cypress Hills do not differ from each other or from the main *T. t. talpoides* population in any character except pelage colour. I feel that this difference is not enough for them to be given subspecific status.

Isolation, or partial isolation, of small groups of pocket gophers from a large adjacent population has

had little or no morphological effect on the pocket gophers currently found in Alberta.

Sample sizes are often limited and often the size of sample which would have been adequate for the study can only be determined after most of the data has been analyzed. In field studies this most often occurs at the end of the summer's work. In this study I found that a sample size of 25 of each sex was adequate for a taxonomic study.

Determination of the number and type of characters to use was an important part of this study. I suggest that in pocket gophers most size characters are concordant. The measurement of several concordant characters yields no more taxonomic information than the measurement of only one character.

I further conclude that numerical taxonomy is not fundamentally different from classical taxonomy although a computer is essential in order to work with the large numers of characters and specimens involved. In many instances, however, large samples and large numbers of characters are not necessary as the same data can often be obtained from smaller samples and in these instances numerical taxonomy is not necessary to obtain meaningful results.

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APPENDIX I

A CHRONOLOGICAL HISTORY OF THE NOMENCLATURE APPLIED TO ALBERTA POCKET GOPHERS

1828	*Cricetus talpoides*	Richardson
1829	*Geomys talpoides*	Richardson
1830	*Saccophorus talpoides*	Fischer
1837	*Geomys borealis*	Richardson
1843	*Ascomys borealis*	Richardson
1843	*Geomys unisucatus* (nomen nudem)	Gray
1843	*Saccophorus borealis*	Richardson
1843	*Ascomys talpoides*	Richardson
1854	*Pseudostoma talpoides*	Audubon, Bachman
1854	*Geomys (Thomomys) talpoides*	Richardson
1858	*Thomomys talpoides*	Baird
1885	*Thomomys talpoides talpoides*	True
1891	*Thomomys fuscus fuscus*	Merriam
1891	*Thomomys clusius fuscus*	Merriam
1901	*Thomomys fuscus talpoides*	Merriam
1915	*Thomomys fuscus fuscus*	Bailey
1915	*Thomomys fuscus loringi*	Bailey
1915	*Thomomys talpoides talpoides*	Bailey
1915	*Thomomys talpoides bullatus*	Bailey
1939	*Thomomys talpoides loringi*	Goldman
1939	*Thomomys talpoides andersoni*	Goldman
1954	*Thomomys talpoides cognatus*	Johnstone

Appendix I (continued)

1955	*Thomomys talpoides fuscus* (dropped from Alberta)	Miller and Kellogg
1964	*Thomomys talpoides talpoides*	J.D. Soper
1964	*Thomomys talpoides cognatus*	J.D. Soper
1964	*Thomomys talpoides andersoni*	J.D. Soper

APPENDIX Ia. DESCRIPTIONS OF TYPE SPECIMENS OF SUBSPECIES OF *THOMOMYS TALPOIDES*

	Type Area	Sex	Number of Mammae	Total Length	Tail Length	Hind Foot Length	Nasal Length	Basal Length	Zygomatic Breadth	Interorbital Width	Length of Upper Molar Series	Interparietal Length	Interparietal Width
T. t. talpoides	Fort Carlton	Male		214	60	28	14	34.5	23	6	7		
	Saskatchewan	Female	12	210	60	29							
T. t. andersoni	Medicine Hat	Male		210	57	28	13		20.8	7.2		4.7	4.7
	Alberta	Female	12	196	55	26	12.8	37	22.2	7.2	7.9	5.1	5.9
T. t. bullatus	Powderville	Male		242	76	30							
	Montana	Female		238	72	30	15.5	37.6	24	6.5	8		
T. t. cognatus	Crowsnest Pass	Male		189	58	26	12.2						8.6
	Alberta	Female	8										
T. t. fuscus	Big Lost River	Male		203	70	27	12.6	33.5	20	6	8.5		8.1
	Idaho	Female	8	205	70	27							
T. t. loringi	Edmonton	Male											
	Alberta	Female	12										

APPENDIX II

c/o Department of Zoology,
University of Alberta,
Edmonton, Alberta,
August 26, 1966.

Dear Sir:

I am presently doing a thesis on the pocket gopher (*Thomomys talpoides*). Although this animal is often referred to as a mole, it is in fact, the only true gopher in Alberta.

I have travelled all over Alberta in an attempt to determine the actual location of gopher populations; however small isolated colonies may exist in areas that I may have overlooked. As you have a more detailed knowledge of your area, could you forward information regarding the existence of any pocket gophers in that location.

The knowledge gained by this study will be used by myself, the Department of Agriculture and Alberta Government Telephones. I am trying to map this distribution by the first week in September, 1966, as I wish to make another map next summer to see the extent of the dispersal of gophers into the new pasture and irrigated lands which we are presently opening up for use.

An early reply would be most appreciated and any information I can return to you will be sent out immediately.

Yours truly,

S.J. MacDonald.

SJM:slk

APPENDIX III

MEASUREMENTS

External Measurements

Total Length (T.L.)	length, in a straight line, from the tip of the nose to the end of the last caudal vertebra.
Caudal Vertebrae (C.V.)	length of the caudal vertebrae.
Hind Foot (H.F.)	measured from the heel (end of the calcaneum) to the tip of the longest claw.
Ear Height (E.H.)	distance from the notch below the opening to the tip of the pinna (exclusive of hair).

Cranial Measurements

Condylo-basilar (C.b.)	distance from the posterior border of the alveoli of the central incisors to the posterior border of the condyles measured along the mid-line of the skull. (Fig. 3d)
Greatest Length (G.L.)	length from the anterior tip of the nasals to the most posterior projections of the skull (Fig. 3c)
Basilar (Br.)	distance from the posterior border of the alveoli of the incisors to the most anterior point of the inferior margin of the foramen magnum. (Fig. 3d)
Basal (Bl.)	the distance from the anterior tip of the premaxillae to the most anterior point of the inferior margin of the foramen magnum. (Fig. 3d)
Zygomatic Breadth (Z.B.)	the greatest distance across the zygomatic arches in a plane perpendicular to the long axis of the skull. (Fig. 3b)

Appendix III (continued)

Cranial Breadth (C.B.)	the greatest distance across the braincase posterior to the zygomatic arches. (Fig. 3b)
Interorbital Width (I.W.)	the least distance between the orbits measured across the frontal bones. (Fig. 3b)
Rostral Width (R.W.)	the width of the rostrum at the level of the apex of curve of the upper incisor. (Fig. 3b)
Molar Width (M.W.)	the greatest distance from the labial side of the upper left molars to the labial side of the upper right molars. (Fig. 3d)
Cranial Depth (C.D.)	vertical distance from a line joining the tips of the incisors to the most ventral point on the posterior part of the cranium (or the molars if the skull sits on the molars and incisors) to the highest point of the cranium. (Fig. 3a)
Palatal Length (Pt.L.)	distance along the midline from a line joining the most anterior points of the posterior border of the palatine bone to the most anterior border of the premaxillary bone. (Fig. 3d)
Palatilar Length (Pr.L.)	distance along the midline from a line joining the most anterior points of the posterior border of the palatine bone to the posterior margin of the alveoli of the central incisors. (Fig. 3d)
Nasal Length (N.L.)	measured in the midline from a line joining the most anterior points of the nasals to their most posterior extensions. (Fig. 3b)
Fronto-nasal Length (F.N.L.)	distance in the midline from a line joining the anterior tip of the nasals to fronto-parietal suture. (Fig. 3b)

Appendix III (continued)

Length of Orbit (L.O.)	greatest distance from anterior to posterior border of the eye socket. (Fig. 3b)
Length of Dentary (L.D.)	greatest length of the dentary bone, excluding incisors. (Fig. 3c)
Alveolar Length of Upper Incisor (I'.L.)	see accompanying diagram. (Fig. 3a)
Alveolar Width of Upper Incisor (I'.W.)	width of upper incisor at level of alveolus. (Fig. 3d)
Interparietal Length (Ip.L.)	distance from the anterior to the posterior border of the interparietal bone. (Fig. 3b)
Interparietal Width (Ip.W.)	distance between the lateral borders of the interparietal bone. (Fig. 3b)
Length of Upper Cheek Teeth (C.T.L.)	crown distance from the anterior border of the anterior premolar to the posterior border of the last molar. (Fig. 3a)
Length of Upper Molar Series (U.M.L.)	crown distance from the anterior border of the first molar to the posterior border of the last molar. (Fig. 3a)
Diastema (D.)	the distance from the posterior margin of the upper incisor alveoli to the anterior margin of the alveoli of the most anterior premolar. (Fig. 3c)
Greatest Width of Scapula (G.W.S.)	see diagram (Fig. 4a)
Greatest Length of Scapula (G.L.S.)	see diagram (Fig. 4b)
Height of Scapular Spine (H.S.S.)	see diagram (Fig. 4b)
Length of Humerus (L.H.)	see diagram (Fig. 4d)

Appendix III (continued)

Smallest Diameter of Humerus (S.D.H.)	see diagram (Fig. 4d).
Length of Femur	see diagram (Fig. 4e).
Smallest Diameter of Femur	see diagram (Fig. 4e).
Baculum Length	see diagram (Fig. 4c).
Does Skull Rest on Incisor and Bulla	Yes or No
Total Number of Vertebrae	self explanatory
Pelage Colour	given a value from (1-6)